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Philosophical Magazine



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AN INQUIRY
INTO THE NATURE OF THE
SIMPLE BODIES OF CHEMISTRY.

BY

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*Axiomata a particularibus rite et ordine abstracta nova particularia rursus  
facile indicant et designant.—NOVUM ORGANUM.*  
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PREFACE.

WHILE there is no department of physical science in which so large a collection of facts has been made as in Chemistry, it must be admitted that, as yet, we have not been equally successful in the discovery of principles, and the establishment of laws. This is mainly to be ascribed to the real difficulties that attend inquiries into the nature of forces acting on the insensible particles of matter, but, perhaps, in part also, to certain prevalent opinions regarding the nature and relations of many of those bodies which form the subjects of observation and experiment.

A fundamental principle, long admitted into every system of Chemistry, is, that there is an extensive order of bodies from which all the others are derived, and which, having resisted the usual agents of decomposition, we are to regard as Elementary or Simple. I propose to shew, that we are not entitled to regard these bodies as elementary or simple, because we have been unable to overcome the affinities of their constituent parts; that they cannot be separated, as natural products, from the bodies which we know to be compound; and that all the phenomena of chemical actions may be equally explained, by assuming the existence of three simple bodies, or two, or one, as of any greater number.

In pursuing this train of investigation, I have treated of the bodies termed Simple in a somewhat more elementary

manner than the case might seem to require ; yet it will be seen that, in order to render the several stages of my argument distinct, it has been necessary that the admitted facts regarding these bodies should be collected, so as to exhibit their mutual dependence. If a sequence can, in any case, be traced, of bodies passing the one into the other, it is manifest that what we can establish with respect to the essential constitution of one, will apply to that of any other of the series. Thus, if we can shew, that any one of the metals is a compound body, we are entitled to assume, that all the other bodies of the same class are similarly formed. Besides, as a further reason for treating of these simple bodies in a more elementary manner, than would be necessary in a memoir addressed to men of science, it will be observed, that, if I shall succeed in establishing my conclusions, the following observations will then become elementary, and fitted to be perused by those who enter, even for the first time, on the study of chemical science.

After having seen that all the bodies termed Simple, may be reduced to a few roots or elements of their own order, we shall necessarily be conducted to the conclusion, that these roots or elements are themselves compound, and derived from other forms of matter. This is the utmost degree of generalization to which I shall attempt to conduct the reader, for the purpose of shewing, that such generalization is consistent with the conclusions which had been already drawn, and confirmatory of them ; and that the assumption of an order of molecules, superior to those of known bodies, is in accordance with the laws of chemical combination, in so far as they have been determined by experiment.

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AN INQUIRY, &c.

I. CHEMICAL ELEMENTS.

It is scarcely possible for any one to engage in chemical inquiries, without feeling that there is something like a want of simplicity and harmony in the relations with which we connect together the members of the first great group of natural bodies, to which, in our ignorance of their composition, we apply the term Simple. The greater number of substances with which we are conversant, are derivable one from another, and are therefore termed Compound; but of the numerous class which we term simple, many are similar to one another with respect to their essential characters, and pass the one into the other by scarcely perceptible gradations, nay, pass into those we term compound, so that no line of natural division can be drawn between the two classes. Yet we hold the one class to be derivative or compound, and the other to be derived from no other bodies; but to be, as it were, distinct products of nature, each formed of particles proper to itself. It is

not enough that we explain the meaning which we attach to the term simple, as applied to these bodies, by saying that we hold them to be simple, because we are unable, by the means at our command, to resolve them into other bodies more simple. This is the mere expression of a fact; but even were the fact established beyond dispute, which it is not, we should not be entitled to regard the bodies in question as simple, in contradistinction to another class which we regarded as compound. By the terms simple and compound, we indicate two Orders of bodies, the most distinct, with respect to their chemical constitution, which we can conceive to exist in nature. But there is no such distinction in the chemical and physical characters of the bodies themselves, as can warrant us in assuming that they are distinct in their nature. The mere circumstance of our inability to compose or decompose the substances in the laboratory, furnishes at the best merely negative evidence. Superior means of analysis, or a better use of the means we possess, may enable us to prove bodies to be compound which we now hold to be simple. But even were it otherwise, we have other means of investigation than the processes of the laboratory, for conducting us to truths in science. We have induction and analogy, without which even experiment would fail to conduct us to the discovery of natural laws. If the bodies which we term simple, present the same general physical properties, and exert the same chemical actions, as those which we term compound, and pass into the compound bodies in their characters and functions, the merely negative evidence, that we are unable to decompose them by overcoming their chemical affinities, should not invalidate the conclusion, that both classes are to be placed in the same order of natural bodies, and cannot be separated the one from the other, by so wide a chasm as a distinct molecular constitution.

But it has become a maxim, in which all chemists have been contented to acquiesce, that a body is to be regarded as simple, because we are not able to shew that it is compound. Yet a juster maxim would be, that a body is to be regarded as compound, when we are not able to prove it to be simple; for the reasons for believing a body to be derived from others more simple than itself, are founded on far stronger analogies than any which have yet conducted us to the opposite conclusion. If it can be shewn that the bodies which we term simple, cannot be placed under an order of natural products, different from those which we know to be compound, we are not entitled to infer that a body is simple, because we have been unable to prove it compound by the agents of the laboratory.

It is surprising that the rule, that a body is to be regarded as simple, because it has not been decomposed, should have been so generally admitted into chemistry, seeing that various chemists have from time to time maintained the opinion, that some at least of the simple bodies ought to be regarded as compound. Thus, Baron Berzelius has given the strongest reasons for believing nitrogen to be a compound body, and has expressed his doubts even as to the composition of the metals. Sir Humphry Davy, in the earlier period of his chemical inquiries, was conducted to the opinion that the bodies sulphur and phosphorus, which give off hydrogen under the influence of voltaic action, might be compound. He even expressed the opinion that all the simple bodies might be compound, and resolvable into hydrogen and some unknown base. He never, however, pursued his own hypothesis to its consequences; and at length he seems to have abandoned it altogether; for no chemist applied more rigidly the rule, that a body was to be held to be simple which could not be decomposed. Upon this principle he established the

simple constitution of nitrogen, which he suspected to be compound, but which did not yield to the agents of decomposition employed by him, and of chlorine, which, mainly upon his high authority, chemists gradually consented to admit amongst the simple bodies. Having proved, by a series of brilliant experiments, that certain substances, the earths and alkalies, which had before been held to be simple, were really compound, he endeavoured to prove, that another body, Iodine, which presented all the characters of a compound body, was really simple. This substance, when first discovered by a manufacturer of saltpetre in Paris, was believed by every one to be a new compound. M. Gay-Lussac, and almost at the same time Sir Humphry Davy, examined it with rigid care. M. Gay-Lussac contented himself with giving an account, the most minute that has yet been given, of its properties. Davy, finding it to resist all the agents which he employed to decompose it, pronounced it to be a simple body, according, as he himself expresses it, "to the just logic of chemical philosophy." The conclusion was acquiesced in by all chemists; but the question was not the more determined, whether this conclusion was arrived at by the rules of a sound logic or by the admission of an erroneous dogma.

The substance in question has many of the characters of chlorine, both in its own actions and in those of its compounds, and it is never found in the natural state but associated with chlorine, or where chlorine may have been. It scarcely differs from chlorine in its properties, more than one body sometimes differs from itself, according to the mode in which it is prepared; and yet, in opposition to analogies of this kind, iodine was at once received into the list of simple bodies, and thus admitted to be not only distinct from chlorine, inasmuch as it was equally a simple product of nature, but to differ, with respect to its molecular

*What are
they -
it is a
simple*

*as Iodine is a simple body
but it is a compound of chlorine
and hydrogen*

constitution, from the whole class of bodies which we term compound, inasmuch as it was simple, and they were derivative.

Of the bodies termed simple, there are now reckoned 55, some of them derived from a few minerals of the rarest occurrence, and some of them found only in minute quantity, associated with some other substance, which they resemble in their general characters. The latest discovered, Lanthanum, was derived from two or three mineral species, all resembling one another, found in the primary rocks of Scandinavia and Greenland, and of the rarest occurrence. But this substance, having resisted the usual agents of the laboratory, was at once pronounced to be simple. Nay, more, from the same minerals which yielded lanthanum, had been derived another body, Cerium, which had long been admitted into every system of chemistry, as a simple body. These two substances resemble one another so nearly, that they are only to be distinguished by some slight differences in fusibility and minor characters, not so great as one body not unfrequently presents, according to the temperature to which it is exposed, and present too many points of resemblance, to allow us to infer that they are distinct from one another, any more than that they are distinct from other bodies which we term compound. Their rarity in the mineral kingdom, and their occurrence in masses of primary rock, which have been subjected, in the revolutions of the earth, to conditions of pressure and temperature, which we cannot produce by art, supply us with abundant reasons for believing them to be the products of pre-existing matter, and not natural elements distinct from one another, and from other bodies, in their molecular constitution. The opposite conclusion arrived at, should convince us that the rule which we have adopted is unsound, and is arrived at, not by "the just logic of chemical philosophy," but by a

Quoted chemical dogma, which ought long ere now to have been banished from the science into which it has been introduced.

In all our inquiries into the chemical nature of bodies, we naturally seek to resolve one substance into others more simple than itself. This is analysis, to which we add synthesis as the highest proof that can be given of analytical conclusions. All the great results which we have yet obtained with regard to the nature of bodies, have been arrived at by following this natural train of investigation. We derive one substance from another, until we arrive at roots or elements which we cannot further decompose. But this proves, in no degree, that the law of continuity is broken at the point where our means of further analysis fail. If we have not the experiments of the laboratory to direct us, we have our reasoning powers. We have induction and analogy, and no one will contend that we ought to reject the aid which these afford us in judging of the unknown from the known.

in physics It is a rule in physics, that we are not to assign more causes for the explanation of an effect, than are necessary to explain it. Now, to explain the varieties of material bodies, as produced by combination one with another, we resort to the supposition of 55 roots or elements. But the supposition of the existence of two distinct roots would equally solve the problem. If we suppose two bodies to exist, A and B, each with its own molecules, we can conceive any number of combinations to be formed. For if A combines with B, there is formed a third body with its own particles $\overline{A + B}$. But $\overline{A + B}$ may combine with A, and then there is formed a fourth body $\overline{A + B + A}$, or with B, and there is formed a fifth body, $\overline{A + B + B}$; and $\overline{A + B + A}$ may combine with $\overline{A + B + B}$, and this new compound again with A or B, and so on through any number of combinations. It suf-

fices, therefore, to account for every possible combination, that we assume the existence of two bodies.

Nor need our generalization stop even at this point. We may admit the possibility of the production of all material bodies from the same order of molecules, that is, from a single body. We know that there are substances as identical in composition as the nicest processes of the laboratory can determine, and yet different in their properties. But bodies different in properties are different bodies, for bodies are only distinguishable from one another by their properties. Similar molecules, therefore, may combine, and form different bodies. The difference between the bodies produced may be ascribed to a difference in the modes of combination, or to the action of unknown forces on the ultimate particles of matter, or to any other cause; but our conclusion is not affected by our hypothesis as to the cause. Having two distinct bodies, however, produced, it is manifest that we can conceive any number of combinations to be formed, that is, any number of bodies to be produced.

All material bodies have a common class of characters; and it is a perfectly natural supposition, that they are all derived from a common order of particles or molecules; and that all the differences which we find to exist between bodies, arise from the different relations of these particles or molecules to one another, and not from a difference in their own nature. This, at least, is a natural idea, and must have suggested itself, in some form or another, to most persons who have pursued this class of inquiries. That matter has been derived from pre-existing particles, was an idea perhaps coeval with the earliest period of philosophical inquiry. When Democritus and the earlier atomists of Greece assumed the existence of pristine elements, they followed out a perfectly natural train of thought, however they may have disfigured the hypothesis by their own bold imaginations.

It is probable that we derive a very imperfect idea of the doctrine of the Greek atomists from the poetic dream of Lucretius. The fancy of the Roman poet is, that matter was produced by a fortuitous concourse of these pristine elements; but it is not certainly known that Democritus and Leucippus thus thought and reasoned. They probably ascribed the union of their elements, not to chance, but to a system of laws; and, if this be allowed, the doctrine of the Greek atomists may be received and approved of by philosophy still.

Of the nature of atoms, molecules, ultimate particles, or by whatever term we express our conception, it is needless to observe, that we know and can know nothing, except from inference. We assume them to be parts of matter, which is simply our definition of an atom, particle, or molecule. We infer that they have weight and extension, for, being parts of matter, they must possess the essential characters by which matter alone is known to us. We cannot conceive a body to have weight and extension, and the parts of which it is composed to be destitute of weight and extension, however far we suppose the division to be carried. Assuming that molecules are parts of matter, we must believe them to have weight and extension, otherwise a molecule is not what we assume it to be, a part of matter. The illustrious Boscovich conceived, of atoms, that they were mathematical points; but this supposition infers that they were not substance, for substance without extension cannot be conceived. The theory of Boscovich, therefore, necessarily conducts us to a doctrine of Universal Forces. If the molecules of matter are merely resisting points, they are not substance but force, and matter itself is a system of forces. This is a very noble conception; but the atom, thus conceived, is manifestly not the atom of the chemist, whose conception of an atom is, that it is a component part

of matter. Philosophy, indeed, may admit, that when we arrive at the ultimate material bodies of the chemist, the law of continuity is still preserved; and that there are existences in the ascending order beyond the atom of the chemist, which have neither weight nor form, and are merely force. But this train of investigation is without the range of chemical inquiry. Chemistry must take matter to be as it is presented to the senses, and all speculation further, must be barren of results with respect to the properties of bodies. If the chemist assumes, as he is almost compelled to do, that matter is composed of molecules, atoms, or particles, he must assume that these particles have both weight and form. Of the absolute weight of his atoms he can know nothing, because he cannot know the number of atoms which constitute any body of a known weight. But he can draw conclusions as to the relative weight of atoms from the law deduced from experiment, that bodies combine in definite ratios. Assuming that molecule unites itself to molecule, it is a legitimate inference, that the weight of these molecules is in proportion to the weight of the bodies which combine. This is really the Atomic Theory due to the genius of Dalton, divested of the useless hypotheses with which it has been encumbered; and, thus understood, the atomic theory of Dalton is one of the happiest generalizations that has been introduced into any science. But we must not carry this theory beyond the limits of a just induction, if we are to apply it to the explanation of chemical truths. We may believe, nay, we must believe, that the particles of matter have weight, because, matter having weight, the parts of which it is composed must have weight. We must believe that they have form, or occupy a portion of space, because we assume them to be substance, and substance cannot exist without form; but the precise form we know nothing of from any data which we have yet

obtained. To deduce the form of molecules from the crystalline shape of certain bodies, is to take for granted the thing to be proved, namely, the connexion between the crystalline shape of the body, and the form of the molecules of which it consists. But we know of no necessary connexion between the shape of a molecule, and the shape which an aggregation of molecules may, under certain conditions, assume. As we know nothing of the shape of a molecule, so we can know nothing of its hardness, indivisibility, or other properties not necessary to our idea of substance ; and, when we employ the atomic theory, we should be careful that we do not assign properties to our molecules which our hypothesis does not necessarily involve. We may speak of the atomic weight of bodies if we will, because this merely expresses a conclusion deduced from the law of the relative combining weight of bodies ; but, when we speak of a solid body as containing so many atoms, or of a volume of gas as containing so many atoms, we employ terms which are inconsistent with the precision which ought to characterize the language of science. The assumption of the existence of ponderable atoms accords with phenomena observed, and enables us to explain results, which we cannot otherwise explain, just as the undulatory theory of light enables us to explain, with singular felicity, the observed phenomena of optics. But the actual state of things may be very different from our conception. We do not, however, hesitate, in either case, to employ our own conception of the law of nature as an instrument of thought for conducting us to the discovery of truths. Thus employed, the atomic theory is of the highest importance, and may be properly used in the language, literal or symbolical, of chemistry ; but then it is to be employed as the expression of our conception of a law, and should imply nothing beyond the idea involved.

We may suppose, it has been said, that all bodies are

capable of being derived from one root or element, formed of molecules proper to itself, or, in other words, from one kind of matter : or else we may suppose, that all bodies are derived from two elements, or simple bodies, each formed of its proper molecules ; or else we may suppose that all bodies are derived from three elements or any given number. If it can be shewn that, in accordance with known laws of chemical combination, we can derive all bodies from one element, or from two elements, or from three, then we are not entitled to assume, that the number of elements is 55, or any greater number than three, two, or one.

In pursuing this kind of argument, we may represent the unknown roots or elements by x , y , and z , or any other symbol, and work out our result in the manner of an algebraical equation ; or we may adopt the method known in arithmetic, as position, or trial of errors, which consists in assuming certain numbers, and correcting them by the results arrived at. But in place of symbols or numbers, we may assume the chemical elements, into which we can reasonably suppose that all bodies may be resolved. Now, there are four roots or elements, into one or more of which, we may suppose that all the other bodies may be resolved, namely, Hydrogen, Carbon, Oxygen, and Nitrogen, because we know already that these bodies extend throughout both kingdoms of nature, and that a vast number of bodies are derived from them. But as there will be seen to be good reason for believing, that nitrogen is a compound body, we need not complicate our argument by admitting it into the number of assumed elements ; but may proceed at once on the supposition, that all bodies may be resolved into three of the number,—hydrogen, carbon, and oxygen. Nor will this selection be made at hazard, for there is reason, founded on the atomic or combining weight of these bodies, for assuming, that all the

others of the class may be resolved into them. The combining weight of hydrogen being held to be 1, that of carbon is nearly 6, that of oxygen nearly 8. Now, we can suppose any other body to be resolved into one or more of these bodies, which have the least combining weight; but we cannot suppose those which have a higher combining weight to be resolvable into any of those which have a lower combining weight. We can suppose, for example, sulphur, whose combining weight is 16, to be derived from hydrogen, carbon, or oxygen, whose combining weights are 1, 6, and 8, respectively; but we cannot conceive hydrogen, carbon, or oxygen, to be composed of, or derivable from, sulphur.

And this is the kind of reasoning which I propose to follow, for the purpose of shewing that the bodies termed simple, may be derived from others in the ascending order more simple than themselves. I shall first assume that the number of roots or elementary bodies is three, namely, hydrogen, carbon, and oxygen, and it will be observed that this process is, in the first stage of the argument, purely tentative. The premises are assumed, and we are to determine how far these premises are confirmed, or otherwise, by the results to be arrived at. The consequences arising from this assumption will be seen in the first column of the following table, in which all the other bodies in the descending order are supposed to be derived from hydrogen, carbon, and oxygen.

But one or more of these roots may themselves be compound bodies. Let it be assumed, in the first place, that one of them is compound. Now, the combining weights of the bodies themselves indicate that which can be derived from the others. The combining weight of oxygen is nearly 8, that of the other two bodies being 6 and 1 respectively. We can therefore suppose, that oxygen can be

assumed to be derived

derived from combinations of the elements, carbon and hydrogen, while we cannot resolve oxygen into one or both of the other elements. This, then, is the second stage of my argument. I shall suppose, that all bodies are resolvable into two, carbon and hydrogen, and this process, it will be observed, is like the other, merely tentative. We assume certain premises, and we are to consider how far the results to be otherwise arrived at accord with the premises assumed. The second column in the table exhibits the results arrived at, by assuming that all other bodies are derived from hydrogen and carbon.

But carbon, one of these elements, may likewise be a compound body, for there is no more reason, founding on the physical and chemical characters of this substance, for assuming that carbon is a simple body, than that oxygen and nitrogen are simple bodies. Carbon may be derived from hydrogen: nay, hydrogen itself may be derived from some other form of matter. This is the last generalization which I shall attempt, and I will endeavour in the sequel to shew, that, by a simple law of continuous combinations, we may suppose both hydrogen and carbon to be compound bodies, and to be derived from a common order of molecules. I shall, in the first place, direct attention to the first two hypotheses, the one, founded on the assumption that hydrogen, carbon, and oxygen, are the roots or elements of all other bodies; the second, founded on the assumption, that hydrogen and carbon are the roots of the other bodies.

The first column in the table, then, shews the possible derivation of bodies from the roots or elements, H, C, and O. The results are obtained, by supposing the several bodies to be formed of single equivalents of each of the assumed roots, the residue accordingly being either H or C. The second column shews the possible derivation of the same bodies from the roots H and C alone. The results of this column

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are founded on those of the former one, the expression $H^2 C$ being substituted for O. The third column shews the combining or atomic weights of the bodies as determined by experiment : the fourth column shews the combining weights as deduced from the assumptions previously made.

Unfortunately the determination of the combining weights of bodies is one of the most difficult problems dependent on chemical analysis. Nearly all the conclusions generally admitted, are founded on the experiments of the illustrious Berzelius. But not only are the experiments themselves exceedingly delicate, but the resolution of the problem to be solved depends partly upon inference ; and, in many cases, we cannot certainly determine, or, at least, we have not yet been able certainly to determine, whether the combining weight obtained is a multiple or sub-multiple of a given number. The one class of mistakes proceeds from imperfections of experiment, the other from the uncertainty of the data assumed. One of the most important of this series of investigations, and apparently not the most difficult to be resolved, was the determination of the ratio of the combining weights of hydrogen and oxygen. This was attempted by two of the most eminent experimenters in Europe, M. Berzelius himself, and M. Dulong together. The medium of three analyses was oxygen 8.009, hydrogen being 1. Now, perhaps few chemical analyses have been made with greater care, and yet the result was only the medium of three experiments ; but a medium of experiments is not necessarily the true result. Of the three experiments made, the result of one must have been above, and that of the other below the medium, and it is merely matter of probability, that the medium was more correct than either the highest or lowest result. Again, the combining weight of carbon was determined by M. Berzelius, to be 6.13. Subsequent experiments, however, and the inferences found on these experiments, have

reduced the combining weight of this body to 6.04. This is probably a nearer approximation to the truth, but, if it has likewise been derived from a medium of experiments, it can only be regarded as an approximation. But these are slight differences ; others are so great, that no dependence can be placed upon the results obtained. The results shewn in the table are necessarily founded on the combining weights, as determined by experiment, making allowance for those slight differences which are within the limits of experimental error. Although I entertain the opinion, that many of the combining weights, as generally received, are very far from the true results, I have not ventured to deviate from the conclusions generally acquiesced in, except in one or two cases in which the number may either be a multiple or submultiple of that commonly received, and in two other cases, in which I conceive the results are manifestly erroneous. These are the cases of boron and lithium. Holding the combining weights of both these bodies to be absolutely undetermined, I shall assume, in the meantime, that the combining weight of boron is the same as that of silicium, which it resembles in its essential properties, and that that of lithium is the same as that of sodium. I have great doubts, too, of the correctness of the number assigned to aluminum, magnesium, and some others.

It is to be regretted, that so much uncertainty should still exist in this fundamental branch of chemical research ; but it is to be confidently trusted, that, by means of multiplied experiments, aided by the beautiful law of Dulong, with respect to specific heat, and by the more recent brilliant generalization of Faraday, much of this uncertainty will be removed. The present argument, however, is not essentially affected by the uncertainty which exists. It matters not with respect to the general conclusion to be drawn, whether the assumed combining weight be a multiple

or submultiple of a given number, nor even whether the combining weights, as determined by experiment, be correct. I assume them to be nothing more than approximate results. I do not accordingly pretend to assign the exact chemical constitution of bodies, at least of those into which a number of elements enter. In truth, the precise formulæ of the latter class of bodies cannot be determined by the rule observed in the table. But if I succeed in proving the derivation of the bodies termed simple, from known bodies of their own order, then I may hope to reduce chemical formulæ to a simple general expression, which may embrace the corrections to be made by further experiment.

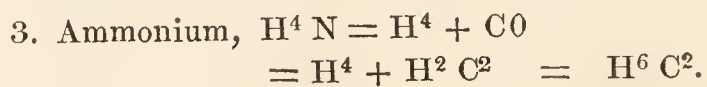
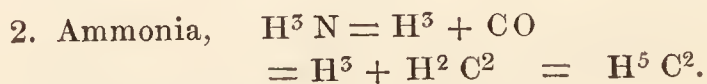
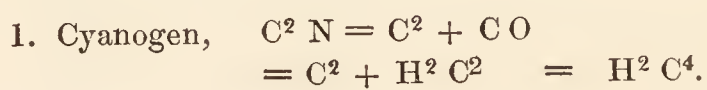
TABLE shewing the possible derivation of the Simple Bodies of Chemistry from common roots.

	1.	2.	3.	4.
SIMPLE BODIES.	Derivation from the roots H, C, O.	Derivation from the roots H, C.	Combining Weights, determined by experiment.	Combining Weights, the roots being H, C.
1. Hydrogen,	H	...	1	1
2. Carbon,	C	...	6.04	6.04
3. Oxygen,	O	H ² C	8.01	8.04
4. Nitrogen,	C O	H ² C ²	14.19	14.08
5. Phosphorus,	H C O	H ³ C ²	15.72	15.08
Or,	H ³ C ² O ²	H ⁷ C ⁴	31.44	31.16
6. Sulphur,	H ² C O	H ⁴ C ²	16.12	16.08
7. Selenium,	H ¹¹ C ² O ²	H ¹⁵ C ⁴	39.63	39.16
8. Tellurium,	H ⁸ C ⁴ O ⁴	H ¹⁶ C ⁸	64.25	64.32
9. Fluorine,	H ⁴ C O	H ⁶ C ²	18.74	18.08
10. Chlorine,	H ⁷ C ² O ²	H ¹¹ C ⁴	35.47	35.16
11. Bromine,	H ⁸ C ⁵ O ⁵	H ¹⁸ C ¹⁰	78.39	78.40
12. Iodine,	H ¹⁴ C ⁸ O ⁸	H ³⁰ C ¹⁶	126.57	126.64
13. Arsenic,	H ⁹ C ² O ²	H ¹³ C ⁴	37.67	37.16
14. Antimony,	H ⁸ C ⁴ O ⁴	H ¹⁶ C ⁸	64.62	64.32
15. Bismuth,	H ¹⁵ C ⁴ O ⁴	H ²³ C ⁸	71.07	71.32
16. Chromium,	H ¹⁴ C O	H ¹⁶ C ²	28.19	28.08
17. Uranium,	H ¹² C ³ O ³	H ¹⁸ C ⁶	54.31	54.24
18. Molybdenum,	H ⁵ C ³ O ³	H ¹¹ C ⁶	47.96	47.24
19. Tungsten,	H ¹⁰ C ⁶ O ⁶	H ²² C ¹²	94.80	94.48
20. Tantalum,	H ² C ¹³ O ¹³	H ²⁸ C ²⁶	184.90	185.04
21. Vanadium,	H ¹² C ⁴ O ⁴	H ²⁰ C ⁸	68.66	68.32
22. Silicium, .....	...	H C	7.41	7.04
Or,	H ⁸ C O	H ¹⁰ C ²	22.22	22.08
23. Boron, .....	...	H C	7.41	7.04
Or,	H ⁸ C O	H ¹⁰ C ²	22.22	22.08
24. Titanium,	H ¹⁰ C O	H ¹² C ²	24.33	24.08
25. Gold,	H C ⁷ O ⁷	H ¹⁵ C ¹⁴	99.60	99.56
26. Osmium,	H C ⁷ O ⁷	H ¹⁵ C ¹⁴	99.72	99.56
27. Iridium,	H ¹⁴ C ⁶ O ⁶	H ²⁶ C ¹²	98.84	98.48
28. Platinum,	H ¹⁴ C ⁶ O ⁶	H ²⁶ C ¹²	98.84	98.48
29. Rhodium,	H ¹⁰ C ³ O ³	H ¹⁶ C ⁶	52.20	52.24
30. Palladium,	H ¹¹ C ³ O ³	H ¹⁷ C ⁶	53.36	53.24
31. Silver,	H ¹⁰ C ⁷ O ⁷	H ²⁴ C ¹⁴	108.30	108.56
32. Mercury,	H ³ C ⁷ O ⁷	H ¹⁷ C ¹⁴	101.43	101.56
33. Copper,	H ⁷ C ⁴ O ⁴	H ¹⁵ C ⁸	63.42	63.32
34. Zinc,	H ⁴ C ² O ²	H ⁸ C ⁴	32.31	32.16
35. Cadmium,	H ¹³ C ³ O ³	H ¹⁹ C ⁶	55.83	55.24
36. Tin,	H ² C ⁴ O ⁴	H ¹⁰ C ⁸	58.92	58.32

TABLE—*continued.*

	1.	2.	3.	4.
SIMPLE BODIES.	Derivation from the roots H, C, O.	Derivation from the roots H, C.	Combining Weights, determined by experi- ment.	Combining Weights, the roots being H, C.
37. Lead,	H ⁵ C ⁷ O ⁷	H ¹⁹ C ¹⁴	103.73	103.56
38. Cobalt,	H ¹⁵ C O	H ¹⁷ C ²	29.57	29.08
39. Nickel,	H ¹⁵ C O	H ¹⁷ C ²	29.62	29.08
40. Iron,	H ¹³ C O	H ¹⁵ C ²	27.18	27.08
41. Manganese,	H ¹⁴ C O	H ¹⁶ C ²	27.72	28.08
42. Cerium,	H ⁴ C ³ O ³	H ¹⁰ C ⁶	46.05	46.24
43. Lanthanum,				
44. Thorium,	H ³ C ⁴ O ⁴	H ¹¹ C ⁸	59.83	59.32
45. Zirconium,	H ⁵ C ² O ²	H ⁹ C ⁴	33.67	33.16
46. Aluminum, .....	...	H C ²	13.72	13.08
Or,	H ¹³ C O	H ¹⁵ C ²	27.44	27.08
47. Yttrium,	H ⁴ C ² O ²	H ⁸ C ⁴	32.25	32.16
48. Glucinum,	H ¹² C O	H ¹⁴ C ²	26.54	26.08
49. Magnesium, .....	...	H ⁶ C	12.69	12.04
50. Calcium,	H ⁶ C O	H ⁸ C ²	20.52	20.08
51. Strontium,	H C ³ O ³	H ⁷ C ⁶	43.85	43.24
52. Barium,	H ¹² C ⁴ O ⁴	H ²⁰ C ⁸	68.66	68.32
53. Lithium,	H ⁹ C O	H ¹¹ C ²	23.31	23.08
54. Sodium,	H ⁹ C O	H ¹¹ C ²	23.31	23.08
55. Potassium,	H ¹¹ C ² O ²	H ¹⁵ C ⁴	39.26	39.16

To which add the following compound bodies:—



II. SIMPLE BODIES OF CHEMISTRY.



I. HYDROGEN.

Hydrogen is so widely diffused in the material world, that it may well be regarded as one of the primary products of nature. It forms an essential constituent of the liquid matter of the globe, and exists in every production of the animal and vegetable kingdom. In the separate state, it is an aëriform fluid, at every known temperature, and under every degree of pressure. It is transparent, colourless, and without taste or odour. It is highly elastic, and the lightest of known bodies. Its specific gravity is .06896, so that 100 cubic inches of it weigh 2.1371 grains.

It is irrespirable, and an animal quickly perishes when confined in it. It does not support combustion, a lighted taper, when immersed in it, being instantly extinguished; but it is itself inflammable, and its combination with oxygen is attended with the evolution of heat, and, in certain conditions, of light. It does not combine with oxygen at low temperatures; but if it be kindled in common air by the application of an ignited body, it burns tranquilly with a feeble light. If the two gases, however, be previously mixed together in certain proportions, and if a body heated to bright redness be applied, or if an electric spark be passed through the mixture, the gases combine on the instant with a flash of light, and loud explosion. In these cases they combine with detonation; but when they are heated to a high tem-

perature without ignition, they combine slowly, and without explosion.

When a stream of this gas is directed on a piece of platinum perfectly clean on the surface, or in a minute state of division, the metal becomes instantly incandescent; and if oxygen gas or common air be present, the hydrogen gas is inflamed; and if the mixture of gases be nearly in the proportion to form water, detonation takes place. It would appear from this action, that platinum condenses the gas by contact, and that the sudden evolution of the latent heat of the hydrogen, is sufficient to raise the metal to the state of incandescence.

An enormous quantity of heat is evolved by the combination of this substance, and the most intense temperature which has yet been caused by artificial means, is produced by its combustion. This effect is applied to use in the oxyhydrogen blowpipe.

The same action that produces heat, produces the most brilliant light that yet has been produced by art. When the jet of the blowpipe is thrown upon a mass of quicklime, the earthy body is heated to a degree of great intensity, and produces a light so white and vivid as to dazzle the eye. When the heated object is placed in the focus of a parabolic reflector, the light is reflected to an incredible distance.

a mistake
Hydrogen gas being the lightest of all known bodies, it is exceedingly convenient to adopt it as the standard by which the combining weight of other bodies is estimated; and it is remarkable that chemists should have preferred taking oxygen for such a standard, in place of a substance so much better suited for the ends of easy comparison.

Hydrogen combines with many bodies, and produces remarkable compounds, one of which is the protoxide, or water.

Water, unlike the substances of which it is composed, assumes the conditions of solid, liquid, and aëriform, within the range of ordinary temperatures. It is a powerful refractor of light, and an imperfect conductor of electricity.

Pure water is, by the universal consent of philosophers, assumed to be the standard with which the weight of all solid and liquid bodies shall be compared. A cubic inch of it at 62° F., or $16\frac{1}{2}^{\circ}$ C., and under the pressure of 30 inches of the barometer, weighs 252.458 grains, and is, therefore, about 818 times heavier than atmospheric air.

Water, from its nature, and the vast range of its affinities, is one of the most necessary agents possessed by the chemist. Innumerable changes are produced by the decomposition and recombination of its elements; and it is the most general solvent in nature. When it combines in definite proportions, it follows the general law of chemical combinations, and its combining weight is the sum of that of its two elements. It has all the essential characters of an oxide, and may be regarded as the type of the class.

It has the property of absorbing and dissolving various gases, in a greater or smaller proportion, when its surface is in contact with them. Thus it absorbs and dissolves from about $3\frac{1}{2}$ to $6\frac{1}{2}$ per cent. of its volume of oxygen gas, and about 100 per cent. of its volume of carbonic acid; and this property fits it for the support of animals that live in water, and for the nourishment of plants, whether under water or on land.

Water combines with a further proportion of oxygen, and forms a remarkable compound. The binoxide or peroxide of hydrogen is a colourless transparent inodorous liquid, of the specific gravity of 1.452, that is, it is 45 per cent. heavier than water. It preserves its liquid form at every degree of cold to which it has yet been subjected; but it is decomposed at a temperature of 59° F., being then resolved

into water, and oxygen gas, and when exposed to the temperature of 212° , it is decomposed with explosion.

It is powerfully acted upon by most of the metals, and many of the metallic oxides, which decompose it, but with different effects. Some of the metals are themselves oxidated, combining with the disengaged oxygen of the peroxide. These are metals which have a considerable affinity for oxygen. Some of the metallic oxides, on the other hand, lose the oxygen with which they were before combined, which passes away along with that of the peroxide. Thus the oxides of gold, silver, lead, mercury, and platinum, metals whose affinity for oxygen is feeble, are decomposed the instant they are brought into contact with the peroxide.

This substance whitens the surface of the skin, and after a time destroys its texture. It acts on vegetable colours, and renders them white. In this and other respects, it resembles the peroxide of sulphur, so that oxygen and sulphur resemble one another in this respect, that, combined in a certain proportion with another body, they exercise a similar action.

Hydrogen combines with sulphur, chlorine, phosphorus, and other allied bodies, and forms a series of compounds which exhibit a common class of properties, and connect together many of the bodies termed simple.

Hydrogen combines with carbon, and forms an extensive group of compounds, chiefly derived from the organic kingdoms, as olefiant gas, naphtha, naphthaline, and many more. The basis of all these bodies may be regarded as HC.

Hydrogen possessing the lowest atomic weight of any known substance, we cannot suppose it to be resolved into any other body known to us. The molecules of hydrogen may therefore be supposed to be more simple than those of other bodies; but it does not follow that the molecules of

See
book

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hydrogen are themselves not derivable from some other form of matter, or that hydrogen should be regarded as forming itself a class distinct from other bodies. In its physical and general chemical characters, it is manifestly in the same class as the other bodies which we term simple, and if they can be shewn to be compound with respect to their molecular constitution, so we must believe hydrogen to be. All that is here contended for is, that, while we can suppose other bodies to be derived from hydrogen, we do not know the form of matter from which hydrogen itself may be derived.

Questions sometimes arise regarding the relations of hydrogen with other bodies. By many it is held to be a metal, and some even seek to find its place amongst particular metals. It is quite possible that hydrogen, if solidified under the necessary conditions, would present the characters of a metal ; but it is equally possible that oxygen, nitrogen, or any other body would do so. It is contended that hydrogen, in certain compounds, takes the place of a metal, and therefore is to be regarded as a metal ; but hydrogen likewise takes the place of oxygen, sulphur, and other bodies, which are not held to be metallic ; and therefore we have no reason to class hydrogen with the metals, in preference to other bodies, with which it is equally associated.

II. CARBON.

Carbon, unlike to hydrogen, exists in the solid form, and is the most fixed of known bodies. It is found in nature in the crystalline state, forming the most beautiful and brilliant of the gems. The diamond is usually colourless and transparent, and it is found likewise of various colours, red, yellow, green, blue, and even black, but always preserving the shining lustre proper to itself. Its specific gravity is 3.520, and it is the hardest substance in nature. Its primary crystalline form is the octahedral, or two four-sided pyramids, of which the faces are equilateral triangles, applied base to base. It is a non-conductor of electricity. It strongly refracts light, which gave rise to the memorable conjecture of Newton, that it was inflammable. When exposed to the solar rays, it becomes, as it were, charged with light, which it gives off again in the dark. Acids and alkalis the most powerful, have no action upon it. In close vessels it resists the most intense heat without fusing; but if it is exposed to a red heat in the open air, or is inflamed in oxygen gas, it is entirely consumed, combining with oxygen.

Carbon is likewise found in the mineral graphite, commonly termed plumbago, or black lead, which contains a quantity of iron; and in the mineral anthracite, which is essentially carbon, but which contains always a portion of hydrogen in combination.

Charcoal consists likewise essentially of carbon, and the foreign matters mixed with it may be separated. Charcoal, as is well known, is most largely obtained from the smothered combustion of wood, but may be obtained from most animal and vegetable substances when ignited in close vessels. The

theory of the action in all these processes is the same. Carbon, hydrogen, and oxygen, form the essential constituents of all organic matter. When, therefore, such matter is exposed to heat, the volatile gaseous elements are thrown off, while the carbon, which is fixed, remains ; and the air of the atmosphere is excluded in the process, because its carbon would otherwise combine with oxygen, and escape.

Carbon, as obtained from charcoal and other vegetable products, and purified from foreign matters, is opaque, and insoluble in water. It now conducts electricity, whereas in its crystalline form it was a non-conductor. It is infusible by heat, and, when excluded from the oxygen of the air, resists the most intense temperature which can be produced by art. Nevertheless, when exposed to the action of a powerful voltaic battery, it is partly volatilized, the attractive force of aggregation being partially overcome ; and a piece of charcoal exposed to this action increases in lustre, and becomes almost as hard as the diamond.

Carbon is inflammable, producing great heat during combustion. When strongly heated in the open air, it ignites and burns slowly, but in oxygen gas it burns with surpassing intensity, throwing off brilliant sparks. When heated, and thrown on nitrate of potassa, it deflagrates with violence, and when it is exposed to a red heat, and nitric acid is dropped upon it, the acid is decomposed, and a shower of sparks is thrown off.

Carbon, in the state of charcoal, possesses the property of condensing within its pores, the air of the atmosphere, and other gases, at common temperatures, and of yielding them again when heated, and different gases are absorbed by it in different proportions. Thus, in the space of 24 hours, it has been found to imbibe 90 times its volume of ammoniacal gas, 65 times its volume of sulphurous acid, 40 times its volume of nitrous acid, 35 times its volume of carbonic

acid, $9\frac{1}{4}$ times its volume of oxygen gas, and $1\frac{3}{4}$ times its volume of hydrogen. It likewise absorbs moisture from the air. When newly made, and left for a day exposed, it has been found to increase in weight 12 per cent. and more, the greater part of which increase of weight is due to the moisture absorbed.

It has the property of attracting the odoriferous and colouring principles of many animal and vegetable substances. Hence it is employed for depriving solutions of their colour, for destroying the offensive taint and effluvia of dead animal matter, and for purifying many substances. From the strong affinity of carbon for oxygen at high temperatures, charcoal is largely employed for the de-oxidation of metallic oxides.

Carbon, on the high authority of Berzelius, has been computed to combine with other bodies in the proportion of 6.13, hydrogen being 1; but, from more recent analyses, its combining weight has been estimated at 6.04.

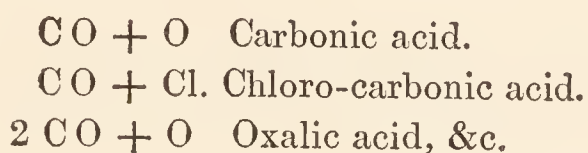
Carbon is found largely in the mineral kingdom in the state of carbonate, and otherwise, and it enters into the composition of all the products of organic bodies. Its combination with oxygen forms two well known substances, carbonic oxide and carbonic acid.

Carbonic oxide is, at all known temperatures, and under every degree of pressure, an aëriform fluid, colourless, without odour, and incapable of being respired. When received into the lungs, even largely diluted with air, it is very hurtful, and when breathed, it almost instantly produces insensibility. It does not support combustion, but is itself inflammable. When set on fire it burns gently, with feeble light, and a lambent blue flame, resembling that of sulphur.

Its density is the same as that of nitrogen, which it also resembles in its action upon other bodies. It differs from

nitrogen in being inflammable, and readily reducible to its elements.

There are strong reasons for believing carbonic oxide to be isomeric with nitrogen, with respect to the number and ratio of its elements. And further, it may be regarded as a secondary root of a great number of compounds, thus :—



Further, the same combination, C O, whether we regard it as forming nitrogen, or carbonic oxide, or an element not yet insulated, may be assumed to be a secondary root of a great number of bodies, thus :—

Ammonium,	.	.	CO + H ⁴
Sodium,	.	.	CO + H ⁹
Calcium,	.	.	CO + H ⁶
Iron,	.	.	CO + H ¹³
Chromium,	.	.	CO + H ¹⁴
Cobalt,	.	.	CO + H ¹⁵
Zinc,	.	.	2 CO + H ⁴
Arsenic,	.	.	2 CO + H ⁹
Strontium,	.	.	3 CO + H
Molybdenum,	.	.	3 CO + H ⁵
Uranium,	.	.	3 CO + H ¹²
Copper,	.	.	4 CO + H ⁷
Tin,	.	.	4 CO + H ²
Antimony,	.	.	4 CO + H ⁸
Bismuth,	.	.	4 CO + H ¹⁵
Silver,	.	.	7 CO + H ¹⁰
Mercury,	.	.	7 CO + H ³
Gold,	.	.	7 CO + H

and so forth, as in the table.

a good example

III. OXYGEN.

This substance exists in the state of an aëriform fluid, at every known temperature, and under every degree of pressure to which it has been yet subjected. It is transparent, colourless, and without taste or smell. It is heavier than air in the proportion of 1102.6 to 1000 ; and hence, while 100 cubic inches of air are held to weigh 31.0117 grains, at the temperature of 60° F. or 15½ C. and under a barometrical pressure of 30 inches, 100 cubic inches of oxygen gas, under the same conditions, weigh 34.19349942. It combines with all the other bodies regarded as simple, with the exception of fluorine, with which it has not yet been made to combine. Its combination with other bodies either takes place slowly, or rapidly, and with the sensible evolution of heat and light ; and bodies which burn in common air, burn, when ignited in oxygen gas, with increased splendour. It is necessary to the respiration of animals, and exists in the air of the atmosphere in a proportion suited to the wants of living creatures, and is dissolved by water in the quantity necessary to support the respiration of the innumerable creatures that inhabit the waters of the globe. It may be breathed in the unmixed state, but its action too greatly excites the system, and death after a time ensues. If a considerable animal, as a rabbit or a dog, is placed in this air, no effect is at first observed ; but after a time, as an hour, the circulation and breathing become rapid, exhaustion at length ensues, then insensibility, and in 12 hours or less, death ; and, on examining the dead creature, the blood is seen to be of a bright red in every part of the body, the heart frequently beating after breathing has ceased ; and on the other hand, no animal is found to live in an atmosphere deprived of this element.

Oxygen, in combining with the other bodies termed simple, forms two classes of compounds, the first termed oxides, the second acids ; and sulphur observes the same laws of combination.

No experiments, direct or indirect, have yet shewn, that oxygen has ever been decomposed, or formed by the union of other elements. In its actions and modes of combination, it exhibits a parallelism with sulphur, chlorine, and even cyanogen. The only known bodies whose atomic weight will allow us to resolve them into oxygen, are hydrogen and carbon. We may suppose that a molecule of each combines and forms a molecule of the root $H\ C$, and that this root, combining with an equivalent of hydrogen, forms $H^2\ C$, which we may employ as an expression for oxygen. A further molecule of carbon, on the assumptions made in the table, constitutes nitrogen $H^2\ C^2$, so that a molecule of nitrogen, on this supposition, differs from one of oxygen by a molecule of carbon.

If we suppose nitrogen to be a compound body, we must, by a parity of reasoning, suppose oxygen to be so ; for there is no such difference in the physical or chemical characters of the two bodies, as can allow us to assume that the one is derivative and the other simple.

IV. NITROGEN.

This substance, constituting about $\frac{4}{5}$ of the volume of the atmosphere, entering largely into the composition of organic bodies, and forming a part of innumerable substances existing in the mineral kingdom, is an element everywhere diffused. It exists at all common temperatures as an aëriform fluid, without colour, taste, or odour, and has not yet been condensed into the liquid state, under any degree of cold and pressure. Its specific gravity is .9722, or according to some .976. It is eminently irrespirable, and no animal can live in it beyond the briefest period. It was thence termed azote, from α privative, and $\xi\omega\eta$ life, in contradistinction to the respirable portion of the atmosphere, then termed vital air. It does not support combustion, and all burning bodies immersed in it are in an instant extinguished. It is not itself inflammable, but it combines with oxygen under conditions favourable to the union, that is in the nascent state, for, when it has passed into gas, it is very difficult to effect the combination. It manifests no acid reaction, and so does not affect the colour of plants, nor combine with the alkalies.

On comparing this substance with oxide of carbon, we find a similarity of characters sufficient to justify the opinion that they are of a similar nature. This latter body exists likewise at all known temperatures, as an aëriform fluid, without colour, taste, or odour, and has not been condensed into the liquid state, under any degree of cold and pressure. Its specific gravity is the same as that of nitrogen, namely, .9722. It is wholly irrespirable, producing, when breathed, almost instant insensibility. It does not support combustion, but, when ignited, burns with a faint blue flame. It thus

differs from nitrogen, in its facility of combining with oxygen, but this is a difference common to other bodies, as the metals in their different states. All the other characters of the two bodies are extremely alike. They are both eminently neutral with respect to other substances. They both combine with chlorine, although this is regarded an anomaly in the case of an oxide, yet it is no anomaly if nitrogen be likewise an oxide of carbon.

An opinion has long been entertained by chemists, that nitrogen is a compound body, and both Berzelius and Davy have eagerly supported this opinion. But as nitrogen has resisted the attempts to decompose it, chemists have been contented to acquiesce in their own dictum, that we must regard it as simple, because we have not been able to prove it compound. The juster argument would be, that we must regard it as compound, although we have not been able to prove it so by the agents we have employed.

But although nitrogen may not have been directly decomposed, there is reason to believe that in numerous unheeded experiments of the laboratory, its compound nature has been again and again shewn. When bitartrate of potassa is distilled, carbonate of ammonia is produced, the nitrogen of the ammonia being beyond a question derived from the carbon and oxygen of the tartrate.

Some years ago I commenced a series of experiments for the purpose of proving directly the composition of nitrogen. But being interrupted in these experiments, and not having since had an opportunity of verifying the results, I shall not here found upon them at all. I am contented for the present to shew by the arguments which induction supplies, that nitrogen is a compound body, and composed of the same elements as the oxide of carbon.

But it does not follow that nitrogen is the same body as oxide of carbon. It is manifest that the elements of these

bodies are related to one another by a different degree of affinity, for while the elements of the oxide may be separated by many bodies, those of the other remain fixed under the most powerful agents of decomposition. Further, the two bodies are in a different relation to heat, for the specific heat of nitrogen is more than that of carbonic oxide. We are not, therefore, to suppose that these two bodies must present the same analogies in their own actions, or in the actions of their compounds, which we assume them to possess in their composition. Thus, we are not to infer that carbonic acid, $\text{CO} + \text{O}$, must be similar in its characters to nitrous oxide $\text{N} + \text{O}$. In carbonic acid the elements of the root are loosely combined, if we may so speak, and the second equivalent of oxygen must have a relation to the root different from that of the equivalent of oxygen to the root in nitrous oxide. While I maintain, with all the confidence that I can place in inductive reasoning, that nitrogen is isomeric with carbonic oxide, in the number and ratio of its elements, I do not maintain that nitrogen is, in all respects, the same body as carbonic oxide.

Hydrogen, or the molecules of hydrogen, it has been seen, may be supposed to combine with carbon, and form oxygen, and oxygen to combine with carbon, or the molecules of carbon, and form nitrogen. But when we arrive at nitrogen in the descending order, there are two groups of bodies almost equally related to it, namely sulphur, phosphorus, and the bodies allied to them, and chlorine and its analogues. It will be convenient to consider, in the first place, the latter class of bodies, which have many characters in common with the sulphur group, and may be regarded as proceeding from a common root. These bodies are fluorine, chlorine, bromine, and iodine.

V. FLUORINE.

It is doubted whether this substance has yet been obtained separately from other matter, although many attempts have been made to insulate it. M. Baudrimont, however, by transmitting fluoride of boron over binoxide of lead, obtained a gas which he conceived to be fluorine, and, by employing another process, he procured it mixed, as he supposed, with hydrofluoric and fluosilicic acids, and he describes it as a gas of a yellowish brown colour, having an odour resembling chlorine, capable of bleaching, and as not acting on glass; and two gentlemen, Messrs Knox, obtained similar results. Other chemists have not been able to verify the experiments: nevertheless, it is extremely probable that the characters given are really those of fluorine, which, in this case, would greatly resemble chlorine.

The combining weight of this substance has been estimated by Berzelius at 18.75, by others at 18.08. It combines with other bodies in a manner so similar to chlorine, that it is impossible to doubt the intimate relation of the two substances.

It combines with hydrogen, forming an acid similar to that which chlorine forms with the same element. Hydrofluoric acid is a colourless liquid at the temperature of 32° F., and retains the liquid state at the temperature of 59° or 60° , provided the external air is excluded, but in open vessels it is dissipated violently in dense fumes. When a drop of it falls in water, a hissing noise takes place, like that produced by immersing red hot iron in the same liquid. It possesses the characters of an acid in a high degree.

Of all substances it is the most corrosive of organic matter. When the minutest portion of it touches the skin, im-

mediate disorganization takes place ; and hence the extreme danger of experiments upon it in the uncombined state.

It dissolves silica, its fluorine combining with silicium, and its hydrogen with oxygen ; so that there are here two affinities called into play, namely, that of fluorine for silicium, and fluo-silicic acid for the water to be generated. It in like manner acts upon boracic acid, whose composition is similar to silicic acid, and on titanite, molybdic, and tungstic acids, whose composition, it is believed, also approaches to that of silica. It acts powerfully upon glass, the fluorine entering into combination with silicium.

Fluorine probably combines with all the true metals, its affinity being greatest for potassium and the other alkaligenous metals, and gradually lessening for the less oxidable ones. With calcium it is found combined in the natural state, forming the beautiful mineral fluor-spar.

The combination of fluorine with silicium forms a colourless transparent gas, having an odour similar to that of hydrochloric acid, which extinguishes flame and irritates painfully the respiratory organs. It has the characters of an acid in a high degree. It is absorbed by water, which it decomposes at the instant of contact, so that when mixed with the air of the atmosphere, it forms a white cloud.

Fluoboric acid, like the last, is a colourless gas, having a penetrating odour, similar to that of hydrochloric acid. It has the acid characters in a high degree. It acts upon water in the same manner as fluosilicic acid, and indicates the minutest quantity of moisture in the air by the white cloud which it forms. It does not act upon glass. These two compounds, then, are extremely similar, indicating a similarity in the nature of the bases, silicium and boron.

VI. CHLORINE.

Chlorine exists at common temperatures in the gaseous state. It is of a greenish-yellow colour, and has a suffocating odour. It is wholly irrespirable, producing, when received into the lungs, even in small quantity, painful spasms, and a dangerous irritation. It may be reduced to the liquid form by a pressure equal to about 4 atmospheres, or 60 lb. on the square inch. It then becomes a limpid fluid of a bright yellow colour, which has not been solidified..

Chlorine gas is absorbed by water, and, at a low temperature, combines with it in a definite proportion. Under certain conditions, it is acted upon by the solar light. If water be present, chlorine gas decomposes the water under the influence of this agent, combining with the hydrogen of the water, and forming hydrochloric acid. The change takes place quickly in sunshine, more slowly in diffused daylight, and not at all in the dark. Chlorine, in combining with certain bodies, produces an evolution of heat and light. All the metals combine with it, and most of them inflame in it, when exposed to heat, and several of them, when reduced to a minute state of division, take fire in it at ordinary temperatures, the chlorine combining with the metal. It has a very powerful attraction for hydrogen, and many of the phenomena to which its action gives rise are due to this affinity. It has the property of destroying the colour of animal and vegetable substances. The presence of water seems to be necessary to this action; the chlorine decomposing the water, and uniting with its hydrogen. Sulphur possesses in some degree this property, and some of its compounds strongly. Chlorine possesses the property of acting

upon the putrid effluvia arising from animal and vegetable substances, and destroying their odour.

The combining weight of chlorine has been calculated at 35.47, though chemists are not agreed on the precise number. It combines with other bodies in the manner of oxygen and sulphur, forming chlorides, just as they form oxides and sulphurets. It exhibits many points of analogy with sulphur, both in its own actions and those of its compounds. The assumed composition of sulphur, as shewn in the table, is $H^2 C O$, or $C O + H^2$; the composition of chlorine is $H^7 C^2 O^2$, or $2 C O + H^7$, so that both bodies may be supposed to be derived from the same secondary root $C O = N$.

Chlorine, like sulphur, combines with oxygen in various proportions. These compounds constitute a group in which the oxygen is connected with the chlorine by slight affinities, and from which it is readily separated. On this account they form substances of great explosive powers. The combination $Cl + O$, instantly destroys vegetable colours in the manner of chlorine itself. And the same property is possessed, though in a fainter degree, by the compound of sulphur with oxygen, $SO + O$.

Chlorine, it has been said, has a great affinity for hydrogen. Hydrochloric acid is at ordinary temperatures in the state of gas, but it becomes liquid under a pressure of 40 atmospheres, at a temperature of 50° . This gas is without colour, and has an acrid suffocating odour, producing spasms. It has intense affinity for water, and whenever it escapes into the air, it is absorbed by the watery vapour, and a dense white cloud appears. If a jar filled with it be opened under water, the absorption of it is immediate, and the water rushes into the vessel with violence. It is in this state of aqueous solution, that hydrochloric acid is chiefly employed, and has been long known under the name of

spirit of salt, and marine or muriatic acid. This solution emits copious white fumes on exposure to the air, freezes at 60° , and, boiling at 110° , gives off hydrochloric acid.

Chlorine, like fluorine, combines with silicium, forming a volatile liquid, which, when exposed to the air, evaporates almost instantaneously in the form of a white vapour.

It likewise combines with boron, forming an acid. The compound is a colourless gas, having a strong peculiar odour. It is rapidly absorbed by water, and is then decomposed.

Chlorine combines with all the other substances with which oxygen and sulphur combine. Its affinity is greatest for the alkaligenous metals, and gradually diminishes for the less oxidisable. Its compounds are of the highest interest in chemical science, in the arts, and in the economy of nature.

The compound body cyanogen presents a close analogy with chlorine in its actions and modes of combination. Now cyanogen is resolvable into nitrogen and carbon $C^2 N$. At common temperatures it exists in the state of gas, but at the temperature of 45° , and under a pressure of 3.6 atmospheres, it becomes a clear liquid, which resumes the gaseous form when the pressure is removed. The gas is colourless, and possesses a strong offensive odour. It extinguishes burning bodies, but is itself inflammable, burning with a purple flame. It supports a powerful heat without being decomposed. It is absorbed by water in large quantity, and then undergoes decomposition. Cyanogen does not, any more than chlorine, exhibit the properties of an acid, but its aqueous solution does, by the production of acids from the mutual decomposition of the cyanogen and water. It combines directly with substances deemed elementary, as oxygen, hydrogen, sulphur, and the metals, in the manner of chlorine. It combines with hydrogen, sulphur, chlorine, and the allied bodies. Hydrocyanic acid $H + Cy$ is a colourless liquid, and is still liquid, when free

from water, at the temperature -64° F. It has a penetrating suffocating odour. It is one of the most deadly of known poisons. It readily undergoes decomposition under the influence of light.

Now, to what are we to attribute this remarkable parallelism between chlorine and cyanogen, the one a body which we assume to be simple, the other a body which we know to be compound? Is it possible to believe, that these substances, so much alike, are yet dissimilar in their essential constitution, and that the one is compound and derivative, and the other simple, and not derived from other bodies? Are we not compelled to believe, that substances so much alike in their chemical actions are of a similar nature, and that what is true of the one, with respect to its constitution, must be true of the other? Can we place in the balance against so many strong analogies, the merely negative result, that we have been unable to decompose chlorine in the laboratory? If such reasoning is allowed in Chemistry, it will be admitted that there is no other branch of physics in which it would be tolerated.

Cyanogen is represented by $C^2 N$, which, upon the supposition made in the table, $= H^2 C^4$, and chlorine upon the same data is represented by $H^{11} C^4$, so that the two bodies, under the suppositions made, present the closest analogy in composition, and both contain the elements of nitrogen. And even independently of the conclusion arrived at by this train of argument, we should have been justified, when we had determined that cyanogen contained nitrogen as a base, in assuming that chlorine likewise contained nitrogen, or the elements of nitrogen, as a base.

VII. BROMINE.

Bromine exists in salt springs and the waters of the ocean, and is found in the ashes of certain maritime plants and marine mollusca. It appears to exist in sea-water, as a bromide in combination with sodium or magnesium, and may be procured from this source. The agent employed to separate it is chlorine, which, from its superior affinity, unites with the base, and sets the bromine free. The bromine is then driven off by heat, in the form of vapour, and condensed in a tube cooled by ice ; but other methods more convenient for obtaining it in quantity may be adopted.

Bromine at common temperatures is in the liquid state. It appears opaque, and of a dark reddish-brown colour, when looked at in a mass, but of a hyacinth-red, when in a drop or thin stratum, and seen by transmitted light. Its taste is acrid and strong, and its odour suffocating and offensive ; from which latter character its name has been derived, *βρωμος*, signifying strong or bad odour. When cooled a few degrees below zero, it congeals all at once, becomes brittle, and it may be said, metallic. It is a volatile substance, emitting, at common temperatures, red-coloured fumes, resembling those of nitrous acid, NO^2 . Its vapour is entirely irrespirable. A lighted taper placed in it, burns for a few instants with a flame green at the base, and red above, and then is extinguished. When certain metals are brought into contact with it, they burst into a bright flame, and burn, as in the case of chlorine, brilliantly. It is soluble, though in small quantity, in water, producing an orange-coloured solution. When in contact with water at 32° , it forms a hydrate of octahedral crystals, of a fine red tint.

When dropped into a solution of starch, it gives it an orange-yellow colour.

It acts upon vegetable colours, and destroys them. It disorganizes organic substances, as wood and muscular fibre. If it touches the skin, it gives a yellow tinge. It is a most fatal poison, if taken internally. A drop of it placed on the beak of a bird, has caused almost instant death. It is, like sulphur, chlorine, and iodine, a non-conductor of electricity. Its specific gravity in the solid state is 2.9966, and the density of its vapour is 5.54. Its combining weight has been calculated at 78.39.

In all its combinations it exhibits the closest parallelism with chlorine. Uniting with hydrogen, it forms an acid in all respects similar to hydrochloric acid. This acid, in the state of gas, has an acid taste and suffocating odour. It is rapidly absorbed by water, and, when mixed with the air of the atmosphere, it forms dense white vapours. It is wholly irrespirable.

Bromine and chlorine, then, are two substances closely connected together, and must be supposed, on every fair presumption, to be derived from some common root. By the table, they are both supposed to be derived from the secondary root C O , chlorine being $2 \text{ C O} + \text{H}^7$, bromine $5 \text{ C O} + \text{H}^8$.

Supposing this to be the composition, or something approaching to the composition of bromine, we can readily enough conceive that bromine may be formed in sea-water, where all the elements required to form it are present; but we can scarcely conceive it to be a physical truth, that two distinct orders of molecules have been created, the one to form chlorine, and the other to form the rare body universally associated with it in the natural state, and which may so easily be conceived to be derived from it.

VIII. IODINE.

This substance so greatly resembles chlorine in its chemical characters and relations, that it is by all chemists comprehended in the same class of bodies. It is found in the waters of the ocean, and in saline springs. It has been found in the oyster, and other marine mollusca, in the sponge and other zoophytes, and largely in sea-plants, from the ashes of which it may be obtained.

Iodine is an opaque solid, of a bluish colour and metallic lustre. It is usually in crystalline scales, but may be obtained from solutions in octahedral crystals. It has an acrid taste, and pungent odour like that of chlorine. It stains the skin of a deep brownish yellow, and, like chlorine, destroys vegetable colours, although its action is more feeble. It fuses at 225° , and enters into ebullition at 347° . But when exposed to even a gentle heat, it rises in the form of a beautiful vapour, which condenses into crystals as it cools. It is from the colour of this vapour, which is of a rich violet, that iodine has derived its name, *ιωδης*. The density of this vapour being 8.7, is greater than that of any known gas.

Iodine is very sparingly soluble in water, requiring about 7000 times its weight of the liquid for solution. It is not inflammable, but, under certain conditions, can be made to unite with oxygen. It is a virulent poison on the animal system, although used in minute quantities as a medicine. It has the property of uniting with starch, and forming a compound which is insoluble in cold water, and distinguished by its deep blue colour. It has an extensive range of chemical affinities similar to those of chlorine and bromine, but less powerful.

Hydriodic acid resembles the corresponding compound of

chlorine in its general characters. It is in the gaseous form, has an odour similar to that of hydrochloric acid, and, like it, reddens vegetable colours. It is instantly absorbed by water, and, when mixed with the air of the atmosphere, white fumes are produced.

The close relation, then, of iodine and chlorine cannot be doubted, and the question naturally arises, whether it is more reasonable to conclude, that these analogous bodies are derived from the same molecules, or that each is composed of molecules, original, distinct, and proper to itself? Surely we ought not to hesitate between the two hypotheses. The bodies themselves have all the marks of being derived from a common root; the one is an abundant product of nature, the other is found only in small quantity, and never but when the other is present, or may have been present.

In the table, iodine is represented by $8\text{ C O} + \text{H}^{14}$, making its combining weight 126.64, which agrees, within a fraction, with that assigned to it by experiment, namely, 126.57. It may be supposed to be derived from the same secondary root as chlorine and bromine, namely, C O .

If this be the composition, or nearly the composition, of iodine, we can have little difficulty in accounting for its existence when sea-water is present. It is nothing that we have been unable to form such a compound in the laboratory. It is formed in the laboratory of the animal and vegetable organs, by a chemistry which we cannot imitate; and this mutation is no more surprising than that of carbon and the elements of water into gum and sugar, nor than the innumerable processes of the animal system by which known bodies are converted into compounds which cannot be produced by art.

IX. SULPHUR.

Sulphur is a solid, brittle substance, of a greenish yellow colour, having little taste, and emitting a peculiar odour when rubbed. It is found abundantly in the mineral kingdom, and is the produce, in an especial degree, of volcanic countries. It is found massive or in crystals, forming a part of many mineral species. It is found especially combined with various metals, as iron, lead, copper, zinc : it exists in all the great series of rock formations, and extends throughout the vegetable and animal kingdoms.

Sulphur is a slow conductor of heat, and a non-conductor of electricity, and, when rubbed, the negative or resinous electricity is excited. Its density is 1.98, being nearly twice that of water. Its combining weight is usually reckoned 16.12.

It melts at the temperature of 216° F. ; it becomes, by further heat, as fluid as water, and of an amber colour, and, being then cast into moulds, it forms the roll sulphur of commerce ; by a further increase of heat, it becomes so viscid, that the vessel in which it is contained may be inverted without its falling out ; by a yet further increase of heat, it becomes again liquid, and if, in this state, it be poured into water, it forms a soft, ductile, transparent mass.

It is a very volatile body, rising in vapour before it is wholly fused. It continues to be driven off according to the heat applied, until at 550° or 600° it is rapidly volatilized. This action, termed sublimation, is usually employed to purify sulphur, which is obtained in the form of crystalline grains known in the arts as flowers of sulphur. When heated in the open air to about 300° F., it takes fire and burns with a faint blue flame, emitting suffocating fumes of sulphurous acid.

It is itself insoluble in water, though, when precipitated from solutions in which it is contained, it unites with a definite quantity of water, forming a white powder, familiarly termed milk of sulphur.

It combines with hydrogen, carbon, oxygen, and nitrogen; with chlorine, and the bodies allied to it; with phosphorus, arsenic, and the bodies of the same class; with silicium, and all the metals; and it may be said with every substance with which oxygen combines. It may in general be substituted for oxygen in the compounds into which the latter enters, and, like oxygen, it forms a class of salts in which it holds the place of oxygen, as well in the acid as the base.

Of its compounds with oxygen, one is sulphurous acid. This substance, S O^2 , is the product of the combustion of sulphur in dry air, or oxygen. It is a gas at ordinary temperatures, but is readily rendered liquid by being passed through a tube, surrounded by a freezing mixture. It is not decomposed at a high temperature, but various bodies, as carbon, hydrogen, and the alkaligenous metals, which have a strong affinity for oxygen, decompose it at a red heat. It has feeble acid properties, and produces a class of salts which considerably resemble the corresponding sulphates, but which are readily decomposed by acids. It acts on many vegetable colours, for which reason the fumes of sulphur are employed to blanch certain substances, as silk and straw.

It may be supposed to be derived from a root S O , which has not been insulated, and may itself be regarded as a secondary root of a series of compounds, thus:—

Sulphurous acid,	.	.	.	.	\text{S O_2
Sulphuric acid,	.	.	.	.	$\text{S O}^2 + \text{O}$
Hyposulphurous acid,	.	.	.	.	$\text{S O}^2 + \text{S}$
Chlorosulphuric acid,	.	.	.	.	$\text{S O}^2 + \text{Cl}$
Iodosulphuric acid,	.	.	.	.	$\text{S O}^2 + \text{I}$
&c.					

Hydrosulphuric acid (HS) exists at ordinary temperatures in the gaseous state, but under a pressure of 17 atmospheres, and at a temperature of 50°F. , it is condensed into a very clear liquid, which re-assumes the gaseous form on the pressure being removed. It has a strong offensive odour. It is very injurious to animal life. The presence of only $\frac{1}{1500}$ part in air was found by the experiments of Messrs Thenard and Dupuytren, to be instantly fatal to a little bird; $\frac{1}{1000}$ part killed a middle-sized dog; and a horse died in an atmosphere which contained only $\frac{1}{250}$ part of its volume of it.

It extinguishes the flame of burning bodies, but is itself inflammable, burning with a faint blue flame, the products being water, sulphurous acid, and sulphur. It is rapidly absorbed by water.

This substance manifests slight acid properties. It resembles water or protoxide of hydrogen in this, that it combines with another equivalent of sulphur, and forms a persulphuret HS^2 , which resembles in a striking manner the corresponding peroxide of hydrogen. M. Thenard, the discoverer of the latter substance, treats at length of these points of analogy. Both have blanching properties, and whiten the skin; both are acted upon in a similar manner by the same bodies. Thus, charcoal-powder, platinum, gold, peroxide of manganese, and the oxides of gold and silver, which effect the reduction of peroxide of hydrogen into water and oxygen, effect the reduction of persulphuret of hydrogen into sulphuretted hydrogen and sulphur.

We need not pursue further the analogies between sulphur and oxygen. They are so great that chemists very generally, in their arrangement of the simple bodies, associate them together as forming a class, but they have omitted to refer this similarity of properties to that which we may fairly

assume to be the cause—similarity of constitution. In the table I have supposed sulphur to be resolved into $\text{H}^2 \text{C O} = \text{H}^4 \text{C}^2$. Oxygen is assumed to be represented by $\text{H}^2 \text{C}$, so that sulphur contains twice the elements of oxygen in precisely the same ratio. This similarity of constitution is in perfect harmony with the similarity of characters, and I cannot accordingly entertain a doubt that the formulæ represent truly the composition of both bodies.

Sir Humphry Davy, in some of his earlier experiments, was led to the conclusion that sulphur contained hydrogen. He found sulphuretted hydrogen to be disengaged, when he exposed sulphur to the action of platinum-points ignited by voltaic action. He found likewise, that, when an alloy of tellurium and potassium was acted upon by melted sulphur, telluretted and sulphuretted hydrogen were disengaged equal to at least 80 times the volume of the sulphur employed. He states, that he made many experiments of this kind with similar results, the sulphur having been sublimed in azote, and moisture excluded with the greatest care; and he remarks, that while, in the experiments with voltaic electricity, it might be supposed that the hydrogen which was evolved, being only in small quantity, was the consequence of accidental mixture, in the other experiment with the alloy, the quantity of hydrogen evolved was too great to allow of such an inference.

These important experiments seem to have remained unheeded by Davy himself, and all subsequent chemists have agreed to regard the result as a consequence of the impurity of the sulphur. It is more probable that a portion of the sulphur itself was decomposed.

If we admit the conclusion to which all analogy conducts us, that sulphur is a compound body, we are necessarily led to the conclusion, that oxygen is likewise compound.

X. SELENIUM.

Selenium is one of the rarer bodies which chemical research has added to the substances termed simple. It has been chiefly derived from iron-pyrites; but it has been found likewise directly combined with sulphur in certain volcanic products, and sparingly, in combination with some metals, as copper, lead, silver, cobalt, mercury. It was first procured by Berzelius, from a manufactory of sulphuric acid, in which impure sulphur was employed. It was found that, in the leaden chamber in which the sulphur was received after combustion, there remained a reddish-coloured matter, which, when heated by the blow-pipe, emitted a peculiar odour, similar to that of horse-radish. This led to an investigation of the deposite, in order to separate the substance to which this odour was owing, from the matters with which it was associated, and the result was the discovery of this new body.

Selenium, when exposed to a heat somewhat higher than that of boiling water, melts, and, on cooling, becomes solid. It is then, like sulphur, a brittle opaque substance, without taste or odour. It has a metallic lustre, and when broken, its fracture has the aspect of lead.

At the temperature of 212° , it is semi-fluid, and at a few degrees higher it is completely liquid. When in its semi-liquid state and cooling, it is so ductile that it may be drawn into fine elastic threads, which exhibit the gray lustre of a metal by reflected light; but which are transparent, and of a red ruby colour by transmitted light. It boils at about 650° F, giving off yellow vapours. When sublimed in close vessels, it condenses into dark drops of a metallic lustre, which unite into larger globules. When sublimed in the open air, it condenses in the manner of sulphur, in a fine

red powder. Like sulphur, it is insoluble in water, a bad conductor of heat, and a non-conductor of electricity, though it is not, like sulphur, rendered electric by friction.

But all the general properties of this substance connect it with sulphur, though it approaches more in its external characters to those substances, which, from their lustre and other characters, are termed metals. It combines with hydrogen, oxygen, chlorine, phosphorus, and doubtless with all the bodies with which sulphur combines, forming analogous compounds. Its combining weight was calculated by its distinguished discoverer at 39.63.

Now, what are the conclusions which we are to draw from the similarity of the characters of sulphur and selenium? Can we believe that a substance like the latter, found in such rarity, and manifestly exercising so slight an influence on the constitution of natural bodies, is a simple body, differing not only from sulphur, but from the great mass of substances which exist in the world, in its molecular constitution? It were hard to believe so, and it were far more reasonable to suppose that selenium is a mere chemical compound, like some of the gems and rarer substances which are found in nature, produced by chemical combinations of other matters existing. We cannot perhaps bring the consideration of final causes into investigations purely chemical; but when we find any thing disproportioned, and out of harmony in nature, we are at least bound to consider whether the seeming want of fitness may not rest with our inferences. Now, how can we infer from the mere fact that we have been unable, by artificial means, to decompose this substance, that it is to be ranked amongst the primary or simple elements of matter? But if we cannot believe selenium to be in this class, so neither can we believe that sulphur is, although greatly more extended in nature; for the two substances are so entirely analogous, that what we believe of the constitution of the one, we must believe of the other.

XI. TELLURIUM.

This substance occurs in the metallic state, chiefly associated with gold, silver, and bismuth. It is of rare occurrence. It has a silver-white colour, passing into leaden gray, with the lustre of a brilliant metal. It conducts electricity, although imperfectly, and heat slowly. Its specific gravity is about 6.2. It is very brittle, and may be reduced to powder. It fuses at a temperature a little higher than the melting point of lead, and when cooled slowly, crystallizes, assuming the rhombohedral form, in which respect it is isomorphous with arsenic and antimony. At a red heat, it is volatilized. In the air it takes fire at a high temperature, and burns with a bright blue flame bordered with green, rising in gray-coloured pungent fumes. It combines with hydrogen, carbon, oxygen, chlorine, and other substances, and in its combinations presents a close analogy with sulphur, connecting it with arsenic and antimony. Its combining weight has been calculated at 64.25. Its formula has been assumed to be $H^3 C^4 O^4$, which indicates 4 times the corresponding elements of sulphur. Similar remarks apply to this substance as to selenium. We cannot without violence to analogy assume that a body so rare is a primary element of nature. It is, therefore, a compound body, and so likewise must sulphur be, which resembles tellurium in all its essential chemical characters.

The chain of connexion between sulphur, selenium, and tellurium, may be said to be unbroken. They present the closest relation in their own properties, in their affinities for other bodies, and in the properties of their corresponding compounds. They all form with 1 equivalent of hydro-

gen a class of bodies resembling one another, all gaseous, and distinguished by a strong odour. Combined with 3 equivalents of oxygen, they form powerful acids, whose salts, the sulphates, seleniates, and telluriates, correspond even to their crystalline form, and the same close relation is exhibited in their other corresponding compounds.

But further, we have seen that these bodies pass into oxygen, between which and sulphur there exists a parallelism of properties, with respect to range of affinities and modes of combination, which strongly indicates a common origin. If we shall believe that tellurium is not a simple body, we are almost compelled to the belief that oxygen is not a simple body.

Nor are the links of the chain broken at tellurium. This body passes by a natural gradation, into others, namely, arsenic and antimony, and the latter, through bismuth, into copper and some of the most perfect of the metals, as will be afterwards shewn. But before proceeding with the description of arsenic and antimony, it will be necessary to advert to a substance, phosphorus, to which they are all related in so far as a common origin produces such a relation, and which itself is directly connected with nitrogen. But we are compelled to break the continuity of the series in this manner, because we are here adopting a linear arrangement, which is rarely that which accords with the natural arrangement of bodies, whether in the mineral or organic kingdom.

XII. PHOSPHORUS.

Phosphorus, so named from $\phi\acute{\omega}\varsigma$ light, and $\phi\acute{\epsilon}\rho\epsilon\iota\nu$ to carry, from its property of shining in the dark, exists in the mineral kingdom, in plants, and largely in animals, from the urine and bones of which it may be readily obtained. It is a soft solid body, nearly of the consistency of wax. It is usually of a light amber colour and semi-transparent, but when entirely pure, it is nearly colourless. By fusion and slow cooling, as well as by precipitation from its solution in naphtha, it may be obtained in crystals. Its mean specific gravity is 1.748. It fuses at the temperature of 108° F, becoming, before fusion, perfectly limpid and colourless, and dilating in volume by .0314, and this liquid, like other very inflammable bodies, possesses a high refracting power. At 217° it begins to rise in vapour, and at 550° it boils, and is converted into a colourless vapour. When exposed to the air it undergoes a slow combustion, which is sensible even at the melting point of ice, and is at length consumed. When undergoing oxidation, it emits a white vapour, having a smell like garlick, and which is luminous in the dark. This slow combustion of phosphorus may be retarded or prevented by increased pressure, and by the presence, in minute quantity, of the vapour of oil of turpentine, and some other compounds into which carbon largely enters. In pure oxygen, we are informed by Dr Graham, the oxidation does not take place at so low a temperature by many degrees, as when the oxygen is diluted with nitrogen, hydrogen, or carbonic acid. When kindled in the air, it burns rapidly, emitting a splendid white light, and producing intense heat; and in oxygen gas its combustion is yet more rapid, and the light evolved more beautiful and vivid. Being

so readily inflammable, it is ignited by a slight degree of heat. A temperature a little beyond that of its point of fusion, 108° F., inflames it readily in the air; nay, friction and pressure between the fingers, suffice to set it on fire, on which account it is usually kept in water, and operated upon in the liquid, and when it is fused, the operation is in like manner performed in water. Further, it may be volatilized even in common air, by mixing with the air a portion of the vapour of oil of turpentine.

Phosphorus is not soluble in water, but, when kept in the liquid, it is gradually covered with a white pellicle, which renders it opaque. It is soluble in small quantity in alcohol, ether, and oils. When the solution in alcohol or ether is mixed with water, the phosphorus rises to the surface, though heavier than the liquid, and takes fire. When the solution in oil is taken to a dark place at a temperature not under 60° , it shines brightly. Phosphorus, like chlorine, is sensible to light, and acted upon by the violet rays of the spectrum.

It enters into combination with hydrogen, carbon, oxygen, sulphur, and other bodies. Its combining weight is reckoned by most chemists to be 31, although others hold it, and perhaps with better reason, to be one-half.

Of the compounds of phosphorus, remarkable ones are formed by its union with oxygen. It unites with hydrogen, forming a substance which has a great analogy with the combination of sulphur with the same element. Under the name of phosphoretted hydrogen, indeed, it is probable that combinations with slightly different equivalents of hydrogen are formed, but be this as it may, these compounds have a strong resemblance to one another, as well as to sulphuretted hydrogen. Now, sulphur and phosphorus are seen by the table to be derived from a common root C O.

All analogy leads us to the conclusion, that phosphorus is intimately connected with nitrogen, which forms so great a

proportion of animal matter ; nay, there is reason to assume that phosphorus is formed in the animal body itself by the action of the secretory organs. We have the proof of a multitude of changes as great as this, produced under the influence of the unknown forces which we term Vital. The changes produced in the blood, under the marvellous and hidden chemistry by which this fluid is made to yield bone, muscle, fat, gastric juice, and all the other products of the animal system, are produced by such actions ; and there is nothing unreasonable in the assumption, that phosphorus, a substance essential to the formation of the entire system of bones, is formed by those actions of secretion and assimilation by which the muscular and other parts of the system are built up.

Ammonia is a constant product of the putrefaction of animal bodies ; but ammonia, we shall find in the sequel, has strong points of resemblance to phosphoretted hydrogen. Now, ammonia consists of hydrogen and nitrogen, or the elements of nitrogen ; and therefore we may believe that phosphorus consists of hydrogen and nitrogen, or the elements of nitrogen. Phosphorus will be seen from the table to be resolvable into $\text{H C O} = \text{H N}$, while ammonia may be represented by $\text{H}^3, \text{C O}, = \text{H}^3 \text{N}$.

The property of emitting light is possessed by phosphorus in a high degree ; but innumerable animals possess the property of emitting light, frequently so vivid, that the smallest objects can be seen by it in the dark. The glow-worm is a familiar instance in our own climates ; but the fire-flies, as they are popularly termed, of the warmer regions, emit a light so brilliant, that they may be employed in place of lamps ; and the whole atmosphere is frequently illuminated by them. Many fishes too, perhaps all fishes, possess in a greater or less degree this property, and, in an eminent de-

gree, the mollusca, and innumerable tribes which inhabit water. The whole ocean, so far as the eye can reach, is often seen in a blaze of light from the phosphorescence of myriads of microscopic creatures, when they approach the surface. But doubtless, the inhabitants of the ocean, every drop of which seems to be filled with living creatures, possess and exercise this marvellous function at the greatest depths, and are thus provided with the faculty of supplying themselves with light, where the rays of the sun cannot reach. Now, we cannot certainly say that the matter which yields these amazing supplies of light is phosphorus, although it is in a high degree probable that it is really phosphorus, or some analogous compound; for it can be separated from the animals, and diffused through liquids, producing phosphorescence. We have, therefore, reason to believe it to be a substance produced by the action of the animal organs; and what so reasonable a supposition as that the basis of this substance is that which enters into the composition of every animal product, whether in the land or water,—nitrogen?

Phosphorescence is not only produced by living animals, but by dead animal matter in a state of incipient decay, as we may see upon every sea-coast where fishes are cast on shore by the waves. The addition of a little nitre, or even common salt, frequently produces or increases the phosphorescence. Even decaying plants emit phosphorescent light, but feebly and rarely, because in plants nitrogen exists in a comparatively minute quantity.

Sulphur, phosphorus, and chlorine, are represented in the table respectively by $\text{C O} + \text{H}^2$, by $\text{C O} + \text{H}$, and $2 \text{C O} + \text{H}^7$, exhibiting a derivation from a common root, and a similarity of composition, which may account for a similarity of properties. If we represent C O in these formulæ by its

equivalent N, we have, as the composition of the three bodies mentioned, respectively $H^2 N$, $H N$, $H_7 N^2$.

We might wonder how, in the ocean, such vast supplies of phosphorus, or compounds analogous to phosphorus, are generated, did we not admit, that all the elements forming it are contained in sea-water. Hydrogen and oxygen constitute the water of the ocean itself; while chlorine, in combination with sodium, containing the same elements as phosphorus, is in contact with every particle of water which the ocean contains.

But if we can conceive the production of nitrogen in the waters of the ocean, it is a slight difficulty to conceive the production of phosphorus. Now, whence is derived that vast supply of nitrogen, of which the muscular substance of all aquatic, as well as land animals, consists? The quantity of nitrogen which water absorbs at the surface is utterly insignificant, and cannot in the slightest degree account for the supply required for that mass of living beings with which the whole body of the ocean seems to be filled. But if we resort to the supposition, that water itself, which probably furnishes the only food of the lower aquatic tribes, and even of many of the higher, contains the elements of nitrogen, we are freed from a difficulty which no other hypothesis resolves. Now water consists of HO ; and O , by our hypothesis, is resolvable into $H^2 C$, so that water contains all the elements of nitrogen; and we have only to suppose its resolution into these elements, by the secretory and assimilating organs of animals, to conceive the production of nitrogen in a quantity which calculation cannot reach.

XIII. ARSENIC.

Arsenic occurs sometimes native, but more often in combination with other metals, and especially cobalt and nickel. On heating these ores of arsenic in a reverberatory furnace, the metal, which is very volatile, is driven off, and, combining with oxygen as it rises in the furnace flues, is condensed into cakes, which, being purified by a second sublimation, yield the arsenic of commerce. The arsenic of commerce, or white oxide of arsenic, is arsenious acid, being a combination of 2 equivalents of arsenic and 3 of oxygen, from which the metal is easily obtained by de-oxidation.

Arsenic has a crystalline texture, and a bright metallic lustre, resembling steel. It is exceedingly brittle, and may be reduced by trituration to fine powder. Its specific gravity is from 5.7 to 5.9. When exposed to heat, it sublimes at the temperature of 365° F., without being liquefied. In close vessels it volatilizes unchanged; but, if atmospheric air be present, it is converted into arsenious acid, by combining with the oxygen of the air. If thrown on a red-hot iron, it burns with a blue flame and white smoke, having the strong odour of garlic, proper to the other bodies of the class. When sublimed, it crystallizes in rhombohedral crystals, being isomorphous with tellurium and antimony.

The combining weight of arsenic is estimated by Berzelius at 37.67, by others at 75.34.

It combines with other bodies in a manner analogous to phosphorus, which it greatly resembles. It combines likewise with the metals, forming alloys, to which it generally communicates the property of brittleness. It combines with hydrogen, forming, in one proportion, a solid, and in another, in which are three equivalents of hydrogen, a very poisonous gas.

XIV. ANTIMONY.

This metal occurs native, but is chiefly derived from one of its ores, the sulphuret, from which it may be obtained, either by heating the sulphuret along with iron filings in a covered crucible, in which case the sulphur combines with iron, or by throwing it in small portions into a red-hot crucible, with substances which yield oxygen to the sulphur, and carry it off as sulphurous acid. In either case, the melted antimony collects in the bottom of the crucible, and may be drawn off and received in moulds, when it is further purified for chemical purposes.

The metal thus obtained is of a silvery colour, and of a bright metallic lustre. It is exceedingly brittle, and may be readily reduced to powder. Its specific gravity is from 6.7 to 6.8. It fuses at the temperature of about 797° F., and in cooling acquires a lamellated structure, and, when it crystallizes, assumes the rhombohedral form proper to tellurium and arsenic. It may be sublimed, at a high temperature, but, when heated in the open air, it takes fire at a red heat, emitting copious fumes of oxide of antimony. When heated to whiteness by the blow-pipe, and thrown upon any hard surface, it burns for a time with great splendour, rolling about. It combines with other substances in the manner of arsenic. Its combining weight is calculated at 64.62. Its probable composition is denoted in the table, by $4\text{ C O} + \text{H}^8$.

Nitrogen, phosphorus, arsenic, and antimony, then, manifest an intimate relation with one another. Their analogous compounds are similar in their crystalline forms. They all combine with 3 equivalents of hydrogen, forming respectively the three gaseous compounds, ammonia, phosphoretted

hydrogen, arsenuret of hydrogen, and antimonuret of hydrogen. Phosphoretted hydrogen and ammonia greatly resemble one another, and the compounds of arsenic and antimony are not less alike in themselves and their compounds. Arsenious acid sometimes replaces oxide of antimony in combination, without changing the form of the compound; and arsenic and antimony are found together continually in the native state.

The probable composition of the four bodies enumerated, is represented in the table thus :

1. Nitrogen,	.	.	CO
2. Phosphorus,	.	.	CO + H
3. Arsenic,	.	.	2 CO + H ⁹
4. Antimony,	.	.	4 CO + H ⁸

XV. BISMUTH.

This metal exists either native, or in combination with other substances, as oxygen, sulphur, tellurium, arsenic, iron. That which is used in the arts is chiefly derived from native bismuth.

It is a substance of a reddish white colour, and of considerable brilliancy. Its structure is highly lamellar, consisting of broad shining plates, adhering together. It is brittle when cold, but when warm may be hammered. Its specific gravity is 9.53, which, by hammering, may be increased to 9.88. It fuses at the temperature of 497° , and expands in cooling. It sublimes in close vessels at a red heat, and when heated to about the same temperature in the open air, it takes fire and burns with a faint blue flame, emitting copious fumes of oxide of bismuth. When heated to whiteness by the blow-pipe, and thrown upon a hard surface, it burns brilliantly, rolling about.

Its combining weight is reckoned 71.07. Its sulphuret, which exists in the natural state, has the same crystalline form as sulphuret of antimony.

The characters of this metal plainly connect it with antimony, so that it forms one of the sequence of substances from nitrogen and sulphur. But it manifests a progressive approach from the frangible metals to the more perfect and ductile, and in many of its properties resembles copper. It therefore distinctly connects the substances we have been considering with the perfect metals.

We might now exhibit the series of the bodies termed simple, continued from bismuth up to the most beautiful and perfect of the metals. In this case a series would be seen to exist from sulphur up to gold, thus :—

Sulphur.	Silver.
Seelenium.	Palladium.
Tellurium.	Rhodium.
Arsenic.	Platinum.
Antimony.	Iridium.
Copper.	Osmium.
Mercury.	Gold.

And this class of bodies may be termed the sulphur group, the several members of it passing the one into the other. I shall not, however, adopt this order of arrangement, because this group of bodies is connected with another, touching upon it at all points, and being more or less connected with it in characters. This other division of the simple bodies I shall call the Siliceous Group, whose type is silicium, which body is distinguished, in an eminent degree, by its infusibility and hardness. But intermediate as it were between the sulphur and siliceous groups, are a few bodies, sparingly diffused in nature, which may be said to connect them together, and not to be very distinctly referred to either. These bodies are chromium, molybdenum, uranium, tungsten, tantalum, vanadium.

XVI. CHROMIUM.

This substance, so named from *χρῶμα* colour, on account of its remarkable tendency to form coloured compounds, was first derived from a beautiful red mineral, dichromate of oxide of lead, obtained in a mine in Siberia, and popularly known as the red lead-ore of Siberia. This ore was used as a paint, but it has now become scarce and costly. The metal has since been found in the chromate of iron, a mineral which is a compound of the oxides of chromium and iron, and which occurs abundantly in Europe and America.

Chromium may be obtained by exposing its oxide, mixed with charcoal, to the heat of a smith's forge, or more readily by forming the chloride of chromium into a paste with oil, and exposing it to a strong heat for an hour, in a covered crucible lined with charcoal. In the one case, the oxygen, and in the other, the chlorine, combines with carbon, leaving the chromium free.

Chromium thus obtained is in grains, and the heat required to fuse it is so great that it has not yet been melted into mass. It has a white colour, intermediate between that of tin and steel, with a shade of yellow. It has a specific gravity of 5.9. It is very brittle, and easily reducible to powder. It undergoes little change by being exposed to the air, or kept under water. It may be likewise obtained by a peculiar process in the form of a finely divided powder of a dark colour, which only acquires the metallic aspect by pressure. In this state it takes fire when heated in the air.

Its combining weight is estimated at 28.19. It unites with the following, amongst other bodies, thus,—

1. Sesquioxide,	.	.	.	.	Cr ²	O ³
2. Chromic acid,	.	.	.	.	Cr	O ³
3. Sesquichloride,	.	.	.	.	Cr ²	Cl ³
4. Terchloride,	.	.	.	.	Cr	Cl ³
5. Sulphur,	.	.	.	.	Cr ²	S ³

It mixes with iron in indefinite proportions, but forms with it one known compound, apparently definite, of a crystalline texture, of a colour whiter than platinum, frangible, and nearly as hard as the diamond.

It is evident that this substance, while it has certain relations with the sulphur group, is yet more closely connected with iron. Assuming the theory indicated by the table, its composition is $H^{14} Cr O$, while that of iron is $H^{13} Cr O$.

XVII. MOLYBDENUM.

Molybdenum is derived from its ores, of which the most common, termed molybdena, is a bisulphuret, usually associated with ores of tin. From this substance is derived molybdic acid, Mo O_3 , and from this, again, the metal molybdenum. The acid, which is a light porous substance, is exposed, along with charcoal, to a strong heat, by which means the oxygen is made to quit the acid. The metal may likewise be obtained, and more easily, by placing the acid in a tube of porcelain, strongly heated, and passing over it a current of hydrogen, which, combining with the oxygen of the acid, forms water.

Molybdenum is so infusible, that it has as yet only been obtained in grains, or in pieces imperfectly agglutinated. Its colour is a silver-white, with a shade of yellow. Its specific gravity is about 8.6, and it is exceedingly brittle. When heated in open vessels, it absorbs oxygen, and is converted into molybdic acid. But its affinity for oxygen is not very great, and hence it is not subject to alteration when exposed to the atmosphere, or kept under water. Its combining weight has been reckoned 47.96. It combines with oxygen, forming—

1. Molybdous oxide,	.	.	MO O
2. Molybdic oxide,	.	.	MO O^2
3. Molybdic acid,	.	.	MO O^3

It combines in a similar manner with chlorine and sulphur.

XVIII. URANIUM.

This metal was first distinguished as a peculiar substance by Klaproth in 1789. He derived it from the mineral pitchblende, in which it exists in the state of an oxide, along with silica, peroxide of iron, and other substances. It is found likewise in a few other minerals, but in comparatively small quantity. It is obtained by different processes. One is founded upon the principle of bringing the metal to the state of an oxide, and then reducing the oxide to the metallic state, by passing over it a current of hydrogen, or by mixing it with charcoal, and exposing it to the heat of a blast furnace. It is obtained in the state of powder, which no heat has yet been found sufficient to melt into a mass. The powder has a reddish brown colour and metallic lustre. Its specific gravity, according to Klaproth, is 8.100, according to Bucholz, 9. It undergoes no change, when exposed to the air at common temperatures, but when heated to redness it takes fire, and is converted into an oxide. Its combining weight has been estimated at 217.26 ; but this is certainly an error, and M. Regnault, founding on Dulong's law of specific heat, reduces it to one-fourth of this estimate, or 54.31. It seems to be allied to chromium, communicating beautiful colours to its compounds.

XIX. TUNGSTEN or WOLFRANIUM.

This metal exists in a few minerals, of which one is tungstate of lime, an opaque white substance, found in Sweden, of great weight, and thence termed tungsten or heavy stone. It was first obtained from this mineral, and afterwards from another, called by the Germans wolfram, which is sometimes found in the mines, and is a tungstate of manganese and iron. From the latter, the metal is termed by the Germans wolfranium. Both these minerals yield tungstic acid $W O_3$, and from this acid is obtained the metallic base, by exposing the acid to the action of charcoal, or of hydrogen, at a red heat, as in the case of molybdenum.

Tungsten thus obtained is a powder of a dark-gray colour, possessing considerable brilliancy. It is brittle, and exceedingly hard. Its specific gravity is about 17.4, so that, next to gold, platinum, and iridium, it is the heaviest of the metals. It is fusible with the greatest difficulty, and when fused has the appearance of steel, and is not changed by exposure to the air. When heated to redness, in its state of powder in the open air, it takes fire, and is converted into tungstic acid. Its combining weight has been estimated at from 94.7 to 97.7. It combines with oxygen, forming—

1. Tungstic oxide,	.	.	$W O_2$
2. Tungstic acid,	.	.	$W O_3$

It combines in the same manner with sulphur and chlorine. It is exceedingly similar to molybdenum, and both are allied to iron and manganese.

XX. TANTALUM.

This metal, discovered in 1801, was derived from a black mineral, with golden streaks, found in the British Museum, and supposed to have been brought from Massachusetts, in North America, on which account, the name columbium was applied to the metal. It was soon afterwards obtained from two other rare minerals, which were named respectively tantalite, and yttro-tantalite, in the first of which it existed along with oxides of iron and manganese, in the second, along with the earth yttria, and it has been found in a few minerals of the rarest species.

From these minerals tantalic acid, Ta O^3 , is obtained, and from this acid the metal. It is in the form of a black powder, which, under the burnisher, assumes the metallic lustre, with an iron-gray colour. It is fusible only at a high temperature, and is not altered by exposure to the atmosphere. When heated in the open air, it takes fire below a red heat, and glows with a vivid light, but without flame, being converted into tantalic acid. Its combining weight has been estimated, doubtless erroneously, at 184.9. It combines with oxygen, chlorine, and sulphur. With oxygen it forms

1. Tantallic oxide,	.	.	.	.	\text{Ta O^2
2. Tantallic acid,	.	.	.	.	\text{Ta O^3

XXI. VANADIUM.

This metal was obtained by Seftstroem in 1830, in the iron derived from the iron-mine of Taberg, in Sweden, and afterwards procured in larger quantity from the slag of the same ore ; and soon afterwards, the same metal was discovered in a mineral in Scotland, in which it exists as vanadate of lead. It is obtained in the form of a powder, which has not yet been fused. It has a white colour, somewhat like silver, and a strong metallic lustre. It has been obtained by another process, in the form of a dark pulverulent substance, which has little of the external characters of a metal, though, by pressure, it assumes a certain lustre. In this state it takes fire when heated in the open air, and is converted into the protoxide.

This metal is so exceedingly brittle, that it cannot be moved from the glass-tube in which it is prepared, without falling into powder. It is but little changed by exposure to the air, but, after a time, its lustre begins to be impaired, and it acquires a reddish tint.

Its combining weight has been estimated at 68.66. It combines with oxygen, sulphur, chlorine, and other substances. Its combinations with oxygen are—

- | | |
|--|-------------------|
| 1. Protoxide, | Va O |
| 2. Binoxide, which has also the properties of an acid, | Va O ² |
| 3. Vanadic acid, | Va O ³ |

This latter acid is fusible, but retains its oxygen at a strong heat. It is very sparingly soluble in water. Like chromium, it has the property of communicating colour to its salts. Its neutral salts are white and yellow, its acid salts a fine orange red.

XXII. SILICIUM.

This substance, although the basis of the most abundant product of the mineral kingdom, has been but recently obtained in the separate state. It may be procured simply by the action of potassium on silica, by which the latter is deprived of its oxygen ; or better, by means of the double fluoride of silicium and potassium. This salt being heated with a quantity of potassium, the latter unites with fluorine, and the silicium is detached. The silicium is then subjected to a powerful heat, in order that it may be freed from a portion of hydrogen which remains attached to it with great force ; and then, in order that it may be freed of some silica which remains mixed with it, an acid is employed, the hydrofluoric, which dissolves the silica, but does not act upon the silicium.

Silicium, as produced by the common processes, is in the form of a powder, of a dark nut-brown colour, which blackens what it comes in contact with, in the manner of powdered charcoal. When heated sufficiently in air or oxygen gas, it inflames, and is partially converted into silica. But after being exposed to a strong heat, it becomes more dense, and has its characters so altered, that it now remains without change under the most intense action of the blowpipe.

From the resemblance of this substance to carbon and boron, it has been proposed to term it silicon, in place of silicum or silicium, the names originally given to it, and still retained by the continental chemists. The propriety of the change of name adopted in England is not very apparent. The term silicon, applied to this substance, is intended to distinguish it from the metals ; but the term metal indicates a difference of form, and not of substance ; and

there is no substantial distinction between metals and other kinds of matter, and therefore the adoption of a term to distinguish silicium from the metals so called, being based on an erroneous hypothesis, should be avoided. Besides, we do not know that the powdery form which this substance assumes, in the common methods of preparing it, is that which, under other conditions, it would assume. If heat could be applied sufficient to fuse the grains, there is reason to believe that they would assume the metallic aspect, just as various metals do. I have more than once found, in preparing this substance, that, for an instant or two, it assumed a colour as bright as silver, which it immediately lost.

Silicium combines with hydrogen, carbon, oxygen, sulphur, chlorine, and other bodies. Its combining weight was estimated by Berzelius at 22.221, on the supposition that silica contains 3 equivalents of oxygen to 1 of base. But silica may contain 2 equivalents, or 1 equivalent of oxygen, to 1 of base, and then the equivalent of silicium would be $\frac{2}{3}$ or $\frac{1}{3}$ of the number assigned to it; and there are distinguished chemists who maintain the latter opinion. M. Dumas, in particular, contends that silica must be held to contain only 1 equivalent of oxygen; and Dr Thomson favours the same opinion. Dr Clark, on the other hand, conceives that silica contains 2 equivalents of oxygen; which would assimilate the constitution of silica to that of carbonic acid. We may adopt the opinion of Dr Clark as being intermediate between the other views; but it is a more probable supposition, founding on the feeble acid powers of silica, that it does not contain more than 1 equivalent of oxygen.

Silica, whether a monoxide or binoxide, is the most abundant product of the mineral kingdom, forming the greater part of the solid crust of the globe, and entering

into the composition of numerous mineral species. As it is obtained by the common processes, it is a white granular powder, gritty to the touch, and destitute of taste. Its specific gravity is 2.65. It is infusible in the strongest wind-furnace ; but in the flame of the oxyhydrogen blow-pipe, it melts into a limpid glass. When obtained in a certain manner, or after being exposed to heat, it is insoluble, or nearly insoluble, in water ; but as it is obtained by other means, it is soluble, or at least combines with water, and forms slightly soluble hydrates. These solutions, when concentrated, produce a gelatinous mass. Silica is found largely in the mineral kingdom in the crystalline form, as in quartz and rock-crystal, leading us to the conclusion, that the earth was once covered with a fluid, holding silica as well as other substances in solution.

Silica exhibits feeble acid characters. It does not even redden the blue colour of plants, and yet it stands in the relation of an acid to various bodies. Thus, combining with the alkalies, it forms glass, and with alumina, the substances termed clays.

The relations of this substance with alumina are very marked. Alumina is obtained, like silica, as a white powder, destitute of taste, but differing from silica in this, that it is soft to the touch, and not gritty. It is insoluble, or nearly insoluble, in water ; yet, like silica, it combines with that fluid, forming hydrates ; and these hydrates, when moist, are gelatinous, like the hydrates of silica. Alumina is infusible in the strongest heat of a wind-furnace ; but by the flame of the oxyhydrogen blowpipe, it melts into a semi-transparent glass or enamel. It is a feeble base, and stands sometimes in the relation to other bodies of an acid ; but its acid powers are slight, and insufficient to redden the blue colour of plants. These characters, common to silica

and alumina, indicate an intimate relation between them ; and further, they are found in close association throughout the mineral kingdom, forming together, not only numerous mineral species, but the great mass of what, in common language, is termed earth. Further relations between silica and alumina conduct us, by an irresistible analogy, to the conclusion, that their bases, silicium and aluminum, are closely connected as natural bodies.

Silicium combines with chlorine, forming a colourless liquid, limpid, and exceedingly volatile. When exposed to the air, this substance is evaporated almost instantaneously, in the form of a white vapour. It has a suffocating odour, resembling that of cyanogen. When brought into contact with water, mutual decomposition takes place.

Silicium, on the suppositions made, is represented by H C ; but if we suppose silica to be formed of 1 equivalent of silicium and 3 of oxygen, silicium is resolvable into $\text{H}^{10} \text{C}^2$.

Whether by any natural processes this substance is converted into carbon by parting with its hydrogen, or whether, on the other hand, carbon, by combination with the same element, is converted into silicium, is not known, although probable in a high degree. If carbon be the primary element, then the silicium, which forms the basis of the solid earth, may not unreasonably be supposed to have been formed by combination of carbon, or the molecules of carbon with hydrogen, or the molecules of hydrogen, in that pristine state of the globe in which natural changes took place, under conditions of pressure and temperature, and by the influence of great masses of matter upon one another, of which we cannot predicate the results from any action now known to us. If, in any former state of the globe, the aqueous portion predominated, as there is reason to believe it did, over the solid, we may perhaps believe that one of the means

of diminishing the volume of water was the combination of its hydrogen with the molecules of carbon to form silicium, and of its oxygen with silicium to form silica.

The well known phenomenon of the petrification of organic substances is exceedingly like a change of their carbonaceous matter into silica. The change into silica of the numerous plants that have been found imbedded in the older sedimentary deposits is so complete, that generally not a vestige of carbon can be detected in them. But if the common solution were correct, that petrification is produced by an infiltration of siliceous particles, the whole carbonaceous matter should remain. Besides, the petrified bodies present the appearance of nothing in any degree like infiltration, but every appearance that indicates an alteration of the particles of the carbon itself as complete as any chemical change. What shall we say to the flint petrifications in chalk? Why should not carbonate of lime infiltrate the matters of the animal rather than silica? The other result may be explained, by supposing that the carbon of the animal has combined with hydrogen, supplied by the water under which the animal matter had been buried during countless ages.

Another natural phenomenon renders it not improbable that there are cases in which carbon is extracted from silica. Great forests grow on sands almost entirely siliceous, in which there seems to be no more carbon than is supplied by the fallen leaves on the surface, and where the trees have extended their roots below the surface into matter in which not a trace of carbon can be detected by analysis. Whence do these trees derive their carbon? It will be answered, from the carbonic acid of the air, which is decomposed in the leaves, the oxygen being set free. It is not denied that carbonic acid is abstracted from the air, and decomposed in the leaves during the day, but it must be re-

membered that, during the night, carbon is given off, and that the difference is so inconsiderable between the carbon abstracted and that given off, that many physiologists are in doubt whether the carbon given off does not equal that abstracted ; and if this were so, it might lead to the conclusion that this decomposition of carbonic acid has other ends than the supply of matter of nutrition to the plant. It is, indeed, an opinion continually expressed, that a function of growing plants is to supply that oxygen to the atmosphere of which it is deprived by the breathing of animals. But this hypothesis, so universally received, is very far from being satisfactorily established. It is known that the clearing away of forests is in every case a mean of rendering the air more salubrious, and that in the highest mountains, and in the circumpolar regions, enveloped in perpetual snow, there is as much, or rather it may be believed there is more, oxygen than directly over the plains covered with the vegetation from which this prodigious stream of oxygen is supposed to be continually evolved. But be all this as it may, there are many reasons for believing that by far the greater part of the carbon which plants consume in growing is derived from the earth ; and it is a supposition not devoid of probability, that silica, acted upon by the fibrils of the roots, furnishes carbon. That the roots of plants are capable of acting upon the hardest rocks appears from this, that a column or a statue formed of siliceous rock will remain for ages as perfect as if it had been chiselled the day before. This may be supposed to be because its smooth surface presents no points of attachment for the seeds of plants ; but let the column or the statue be overthrown, and broken, or be so placed that plants may grow upon it, and we shall find that it becomes subject to disintegration and change ; plants take root upon it, first the fungi and lower tribes, and then the more developed

species, until at length it becomes a part of the soil. From these and other considerations upon which I will not here dilate, plants seem to possess the power of appropriating the matter of the harder minerals to their uses, and so perhaps of deriving even carbon from siliceous matter.

Whether in the numerous processes of the laboratory, changes of carbon into silicium take place, is not easily determined. Chemists are sometimes startled by results which do not accord with known chemical actions, and this being so, the results are ascribed to impurity of the substances employed, or to errors of experiment; but more frequently analyses themselves are partial and imperfect, and the whole results are not observed. It is far, therefore, from being an improbable supposition, that, amongst thousands of experiments, there are many in which the change in question has taken place.

XXIII. BORON.

Boron is derived from boracic acid which exists in several minerals, and especially in the impure alkaline salt, borax, a substance derived from certain elevated lakes in Thibet, which dry up in summer, leaving the borax as an incrustation. It was long familiar in Europe, for the fusing of metals, and for forming glass employed to imitate gems. But boracic acid is now chiefly obtained from certain hot pools in a district of Tuscany, the water of which is charged with the free acid, apparently derived from volcanic vapours. The boron may be obtained by heating the acid along with potassium, by which means it is deprived of its oxygen; but boron may be procured by better means from the double fluoride of boron and potassium. It is obtained as a dark olive-coloured powder, destitute of taste, smell, and metallic lustre. Like silicium, it is a non-conductor of electricity. When heated in vacuo, or close vessels, it bears the most intense heat that can be applied, without fusing, or undergoing any change, beyond an increase of hardness and density; but if heated in the open air to 600° , it takes fire suddenly, and burns with brightness, forming boracic acid, which fuses as it is formed. It is insoluble in water, in ether, alcohol, and oils.

The combining weight of this substance has been very variously estimated, according to the views taken of the constitution of its compounds. M. Berzelius estimates it at 10.91, on the supposition that boracic acid contains 3 equivalents of oxygen. M. Dumas draws a different conclusion, and Dr Thomson estimates its combining weight at 8, on the supposition that boracic acid consists of equal proportions of oxygen and boron.

Boracic acid has been long known in medicine and the arts, in the alkaline salt, borax. It is found native in certain waters, apparently in contact with volcanic vapours, and it is a constituent of several minerals. As it is obtained from borax by the action of sulphuric acid, it is in the state of a hydrate, which may be rendered anhydrous by the application of heat. It has a bitter taste, and is destitute of smell. Its acid properties are feeble. It reddens litmus paper slightly, but, like the alkalies, renders turmeric paper brown. The weakness of its acid properties is further manifested in its saline compounds, all the borates in solution being decomposed by the stronger acids. The anhydrous acid fuses readily, forming a hard, colourless, transparent glass, and this property of ready fusibility it communicates to its compounds, on which account borax is employed as a flux.

Boron combines with chlorine, but the product is not liquid like the chloride of silicium, but in the state of gas at common temperatures. It is rapidly absorbed by water, and then decomposed. When it is brought into contact with moist air, a dense cloud of vapour is produced.

Although in these combinations, and still more in those with hydrogen and fluorine before referred to, a great analogy is observed between silicium and boron, there are certain differences which prevent us from assuming, that they are precisely the same substance. But they are both connected in an intimate manner with carbon, and it cannot be doubted are derived from it as an immediate root. But boron and silicium differ in their relations with the great mass of mineral products in this, that while the one is diffused throughout the whole earth, the other is found only in a few localities, and has manifestly been produced under peculiar conditions. So far as observation yet shews, boron is formed in connexion with volcanic agents. Now, what

is the conclusion which we ought to draw from this ? Not surely that boron and silicium are distinct products of nature, each formed at the beginning of matter proper to itself, but that the one is either derived from the other, or that both are formed from a common root. Silica constituting the greater part of the solid matter of the earth, and extending to the sources of volcanic action, or at any rate acted upon by the heated matter of volcanoes, it is easy to conceive how its constitution may be so altered by so powerful an agent as to place its elements in a different chemical relation to one another. If both consist of carbon and hydrogen, or any other supposable form of matter, nothing is so likely as that silica, in the vast natural crucible in which its products are contained, may give rise to another body similar to itself. Such a supposition is in accordance with the known laws of chemical changes. The supposition that Nature has found it necessary, if we may use such an expression, to form two distinct kinds of matter, the one in the smallest quantity, and in no sensible degree, so far as we know, influencing the constitution of the great mass of mineral substances, seems to be opposed to a just analogy, and inconsistent with the simplicity of natural laws.

XXIV. TITANIUM.

This metal was first obtained from a black sand found in Cornwall, resembling gunpowder, composed of titanitic acid and protoxide of iron, and it has since been discovered in a few other minerals. It has likewise been found in crystals of titanitic acid, taken from the bottom of the smelting furnaces of large iron works.

Titanium may be procured by subjecting the acid along with charcoal to the most powerful heat of a wind-furnace, which reduces the acid, but does not fuse the metal. It may likewise be procured from the chloride, in the state of a deep blue-coloured powder, which burns when exposed in a heated state to the air. But after it has been subjected to a high temperature, it becomes incombustible, harder, and denser, and is no longer acted upon by acids. These are the characters of silicium, which this substance further resembles in its combinations. Its combining weight has been calculated at 24.33. It combines with oxygen, chlorine, and sulphur, and doubtless with many other bodies; but its compounds have been only partially examined. Its combinations with oxygen are—

- | | | |
|-------------------|---|-------------------|
| 1. Titanic oxide, | . | Ti O |
| 2. Titanic acid, | . | Ti O ³ |

The latter substance is a white powder, which acquires a yellow tint by heat. It is insoluble in water, and infusible; but, like silica, it may be obtained in the state of a white gelatinous precipitate, which is soluble in diluted hydrochloric acid. When this precipitate is dried and heated, it glows, and is then no longer soluble in any acid.

From this account of titanium, no doubt can exist that it is closely allied to silicium. Further, it so nearly resembles zirconia that the two bodies are with difficulty distinguished, and is thus seen to be one of the links which connect the siliceous group of bodies with the aluminous.

These three substances, then, silicium, boron, and titanium, may be said to constitute the siliceous series of undecomposed bodies. They are few in number, but of vast extent with relation to other mineral products, since one of them, silicium, forms the basis of the greater part of the matter existing on the globe.

The other bodies regarded as simple are all metals. They may be conveniently arranged, nearly in the order in which they combine with oxygen, placing at the head of the scale gold, which is the most electro-negative, and exhibits the least affinity for oxygen, and at the bottom of the scale potassium, which has the greatest affinity for oxygen, and may be regarded as electro-positive with relation to all the others. The manner in which the sulphur and siliceous groups are related to them may be illustrated thus:—

Sulphur, Arsenic, Antimony, &c.	Gold.
	Osmium.
	Iridium.
	Platinum.
	Rhodium.
	Palladium.
	Silver.
	Mercury.
	Copper.
	Zinc.
Silicium, &c.....	Cadmium.
	Tin.
	Lead.
	Cobalt.
	Nickel.
	Iron.
	Manganese.
	Cerium and Lanthanum.
	Thorium.
	Zirconium.
	Aluminum.
	Yttrium.
	Glucinum.
	Magnesium.
	Calcium.
	Strontium.
	Barium.
	Lithium.
	Sodium.
	Potassium.

Bismuth, it was seen, passes into copper, copper passes into zinc, zinc into tin, tin into lead, and so on to iron and the alkaligenous metals. The whole members of the group are thus connected with one another, and with the other bodies termed simple, exhibiting a concatenation of parts, which can be accounted for only by a common derivation.

XXV. GOLD.

Gold, although not the most useful, has in every age been regarded as the most precious, of the metals; a distinction which it owes to its rarity, its beauty, its indestructibility, and other properties. It occurs in the metallic state, either pure, or alloyed with silver, or other metals, and frequently with iron pyrites. It occurs crystallized in the cubic or allied forms, in veins and threads, but is often so disseminated in the mass of rock as to be only detected by pounding and washing. It is, however, most abundantly found in the sand of rivers and other alluvial deposits, into which it has been carried. In this condition it is found in Brazil, Mexico, and Peru, in Africa, and in the river sands of many countries. The chief supplies of it are derived from Mexico and South America, from the mines of Hungary, and more recently from the Oural Mountains.

Gold is easily separated from the alloys and extraneous bodies with which it is found. When pure, it is of a yellow colour, which distinguishes it from the other simple metallic bodies. Its lustre is considerable, but even when burnished, it is inferior in brilliancy to silver, steel, or mercury. Its specific gravity is from 19.4 to 19.6. It is soft, and very flexible. It is of all the metals the most ductile and malleable. It may be beaten into leaves of surpassing tenuity. It melts at the temperature of about 2016° F., and when in the melted state, assumes a bluish-green colour. It expands more in the act of fusion, and consequently contracts more in cooling, than most other metals, and hence it is not well fitted for forming casts from moulds. It is in no way altered by water or air, and hence it may be exposed for ages to moisture and the atmosphere without having its surface

corroded. It is not oxidated by being kept in a state of fusion in open vessels; but it may be ignited by the powerful action of electricity or the oxyhydrogen blow-pipe, and then it burns brilliantly with a greenish-blue flame, and is dissipated in the form of a purple powder. It is not oxidated and dissolved by any of the pure acids. But chlorine combines with it, and hence it is dissolved by nitro-hydrochloric acid, which supplies chlorine, and this acid, on account of its dissolving gold, was distinguished by the older chemists as *aqua regia*.

The combining weight of gold is estimated by some at 199.2, by others at one-half. It combines with oxygen, chlorine, sulphur, and other substances, and forms alloys with bodies of its own class.

Gold, regarded in all ages as the noblest of the metals, is yet connected with the others of the class, by characters which place it beyond dispute, in the same natural group. It passes through platinum, silver, and mercury, into copper, and through copper, into tin, lead, and other metals. Copper, it has been seen, is connected by the closest relation with bismuth, antimony, arsenic, and these again with sulphur, and so on to nitrogen and oxygen. Gold, therefore, with all its beauty and perfectness of metallic characters, is no other than a sequence of a chain of bodies; and what we believe of any one of them, with respect to its essential constitution, we must believe of gold.

XXVI. PLATINUM.

Whilst gold has been the object of desire from the earliest times, platinum, not less to be ranked amongst the precious metals, and for certain of its uses more valuable than gold, was unknown in Europe till about the middle of last century. It has been found in Brazil, in Peru, in the mine of Santa Fe, near Carthagena, at Santa Rosa, in the province of Antioquia, where it occurs in veins associated with gold, and in the valley of Jaky, in St Domingo. It has been detected in the silver mines of Guadalcanal, in Estremadura. But the richest mines of it yet known, are on the east side of the Oural Mountains, where it was discovered so lately as the year 1820, and whence it is obtained in such quantity, as to be used as coin in the Russian Empire.

It occurs in the form of small rounded or flattened grains, which, in rare cases, are of the size of a pea and upwards. Its particles are found mixed with sand, and other substances, in alluvial depositions, and it is said likewise to have been found *in situ* in disintegrated syenite. It occurs, likewise, in veins, chiefly, it would seem, in syenitic rocks, in the form of heavy grains, darker than silver. The grains of native platinum usually contain from 75 to 85 per cent. or more of that metal, with frequently so much of iron, that they are magnetic, together with small quantities of palladium, iridium, osmium, rhodium, and copper.

Platinum is purified from the substances with which it is associated, by processes of considerable labour, and is obtained in a state of minute division, in which condition, it is frequently termed spongy platinum. It is then, by pressure and heat, converted into bars or ingots. The perfecting of these processes is due to the late Dr Wollaston, who

thus contributed greatly to the advancement of chemical science, by supplying to the operator vessels formed of a metal which resists the action of powerful agents, and is nearly indestructible by the greatest heat which the chemist has occasion to employ.

Platinum, when pure, resembles silver, in colour and external characters, but is of a lustre much inferior to silver. It is the heaviest of the metals, and of any known substance. Its specific gravity increases somewhat by hammering, its maximum being 21.5313. It is highly malleable, though less so than gold and silver. It may be hammered into leaves, which do not exceed the $\frac{2}{1000}$ part of an inch in thickness. Its tenacity is so great, that a wire of it, of .078 of an inch, is capable of sustaining a weight of 274.31 lb. avoirdupois. It is infusible by the most intense heat of a smith's forge, but it softens at high temperatures, and may be welded by hammering, like iron. Under the powerful action of galvanism, or the oxyhydrogen blowpipe, however, it may be fused. On heating a small wire intensely by these means, it melts, and then is dissipated with the emission of bright sparks. This property of extreme infusibility, platinum loses by admixture of other substances; and hence, while impure platinum may be fused, that which is pure will not be affected. It is in no degree acted upon by air or moisture; but, when ignited with certain bodies yielding oxygen, as nitre, it undergoes oxidation. It is not acted upon by any of the pure acids. Its only solvent is chlorine, or such solutions as supply it; and hence, nitrohydrochloric acid, so long known as the solvent of gold, is likewise the solvent of platinum.

Platinum is obtained in the most perfectly divided state, by dissolving the protochloride in a hot concentrated solution of potassa, and dropping into it alcohol, which causes a violent effervescence. The precipitate, when freed of

foreign matters and dried, resembles lamp-black, and soils the fingers like silicium in the same condition, and it is not till this powder is exposed to a white heat, that it re-assumes the metallic aspect.

Platinum, it was before observed, when a stream of hydrogen, in connexion with oxygen, plays upon it, causes instant condensation and combination of the gases, with an evolution of heat so great as to raise the platinum in an instant to incandescence. The same action is manifested when the platinum is reduced to powder. The powder, too, absorbs and condenses gases with its interstices and pores, in the manner of charcoal.

The combining weight of platinum has been estimated at 98.84. It combines with oxygen, chlorine, sulphur, and other bodies, and with the bodies of its own class forming alloys.

XXVII. OSMIUM.

When crude platinum has been dissolved in hydrochloric acid, a part remains undissolved in the state of a black powder. This powder is an alloy composed of the two metals, osmium and iridium, from which the osmium is separated by means of fusion, with soda or nitrate of potassa. It is obtained as an oxide, which is easily reduced to the metallic state. Thus obtained it is a black powder, which, by pressure, is rendered compact, when it acquires a white colour, and metallic lustre, but less brilliant than that of platinum. It is brittle, and easily pulverized. When in the state of powder, as it is obtained from the oxide, it takes fire when heated in the open air, burning without residue, and it is readily oxidated by nitric acid. But when rendered dense by the application of a red heat, it is not attacked by acids, and may be heated without undergoing oxidation. Its specific gravity, when most dense, is 10. Its combining weight has been estimated at 99.7, and it forms the following compounds with oxygen,—

1. Protoxide,	.	.	.	.	.	Os O
2. Sesqui-oxide,	.	.	.	.	.	Os ² O ³
3. Binoxide,	.	.	.	.	.	Os O ²
4. Teroxide,	.	.	.	.	.	Os O ⁵
5. Quadroxide, or osmic acid,	.	.	.	.	.	Os O ⁴

The latter compound is produced by the combustion of osmium, by its oxidation by acids, or by its being fused along with nitrate of potassa. It is obtained in the form of brilliant white crystals, or in an aqueous solution which yields crystals on cooling. It is volatile, and has a pungent offensive odour resembling that of chlorine, and its vapour, like that of chlorine, is very acrid, producing cough and painful feelings. Osmium, too, combines with chlorine, sulphur, and other bodies.

XXVIII. IRIDIUM.

Iridium is obtained from its alloy with osmium, by a series of processes. It is an exceedingly brittle metal. It has, when fused, the aspect of platinum ; but it is of all known metals the most infusible. It has resisted the attempts to melt it by the most skilful chemists, and has perhaps been really fused only once, and this by the action of the most powerful galvanic battery that has yet been constructed, namely, that of Mr Children. The specific gravity of the little globule obtained was 18.68; that of the unfused metal is 15.8629. If when in a fine state of division it is exposed to a red heat in the open air, it becomes oxidated. It resists the action of all the acids, except the nitro-hydrochloric, and even this acts upon it feebly. Its combining weight is estimated at 98.8, being the same as that of platinum, and its combinations are analogous to those of osmium.

XXIX. RHODIUM.

Rhodium, like palladium, iridium, and osmium, is found associated with platinum. It is obtained in the state of a black powder, but being fused, for which an intense temperature is required, it has the colour and lustre of platinum. It is brittle, hard, and capable, when fused, of resisting the action of all acids, but when alloyed with certain metals, it dissolves along with these metals in hydrochloric acid. Its solutions have a fine rose-colour, whence its name *ῥόδον*, a rose. Its specific gravity is about 11, and its combining weight is estimated at 52.2. Its combinations, so far as they have been examined, are similar to those of the other bodies of the same class.

XXX. PALLADIUM.

Palladium is obtained from an acid solution of the crude ore of platinum. It is precipitated from the solution in the form of a powder, which is rendered malleable by a process of purification and alternate heating. The metal resembles platinum in its external characters, being, like it, of a white colour, and in lustre inferior to silver. It is malleable like platinum, but more hard; it is more fusible than platinum, and, when intensely heated by the oxyhydrogen blowpipe, is dissipated in bright sparks. It is not acted upon by exposure to the air, but when strongly heated in oxygen gas, its surface acquires a fine blue colour manifesting the commencement of oxidation. It is acted upon by nitric, and even by sulphuric acid, in which respect it differs from platinum, which is not acted upon by these acids; but its proper solvent, as in the case of gold and platinum, is nitrohydrochloric acid. Its density is about 11.8, being little more than half that of platinum, and its combining weight is computed to be 53.36. Its combinations, in so far as they have been examined, are similar to those of the bodies of the same class.

These five bodies, then, platinum, osmium, iridium, rhodium, and palladium, are all connected together, and possess the same general physical and chemical characters. The existence of this single group of bodies should of itself demonstrate, that the theory of the existence of 55 distinct elements cannot be maintained. Even if it could be conceived that platinum was a distinct chemical element, how could it be conceived that iridium likewise was so, found only in connexion with the other, possessing all its essential

properties, and not differing more from it than some other bodies do from their normal characters after being subjected to a red heat and before? We treat with ridicule the opinion of the alchymists, that the elements were three,—salt, sulphur, and mercury; but two of the three we still retain as elements, and, although we now know that the other is not an element, the discovery does not date far back in the history of chemical science. In place of this elementary salt, we have now more than 50 elements, so that if we have corrected the opinion of our precursors in this one point, we have erred at least in an equal degree in another direction. In seeking to reduce all bodies to simple elements, the early cultivators of chemistry followed out, though with imperfect lights, a natural train of thought. They had even improved upon the earlier conception, that the elements were four,—earth, air, fire, and water. But even this latter idea was a natural one. For earth, air, and water are still in one sense the root of many bodies, though the earlier philosophers did not know that there were many earths and airs, and that water was derived from elements more simple than itself; and with respect to their element of fire, we can hardly say that the idea was extravagant, when we know, that almost until the age in which we live, the same doctrine, modified into the theory of phlogiston, retained its place among the admitted truths of science.

Platinum and the allied bodies are found in the oldest rock formations, or in their detritus washed into crevices, hollows, and plains. In this respect platinum is found under the same conditions as gold, tin, and other perfect metals, which are generally found in veins, sometimes in threads as fine as a hair, passing through the mass of rock with which they are associated. Many theories have been proposed to account for the production of metals under these circumstances. One of the latest ascribes their formation

to electrical agency. We are the less entitled to reject this hypothesis, now that we know the close relation, if not the absolute identity, of chemical and electrical forces, so that when we ascribe an effect to electricity, we may be said to ascribe it to a chemical action. But the hypothesis infers that the matter on which the agent acted was already formed. Now, what was the matter? Was it a set of molecules, proper to each metal to be formed, and the sole element of each metal, which in this case only could be called a simple body. Or was each metal formed by new combinations of pre-existing elements? We have a knowledge of the one kind of change in every chemical combination; but of the other kind of action we have no knowledge whatever. The solid crust of the earth consists essentially of silica, alumina, lime, magnesia, the oxides of iron, soda, and potassa. Each and all of these may be supposed to possess the materials for forming new products, and amongst these products, the class of crystalline bodies which we term metals; and we should no more hesitate to believe that gold, platinum, and silver have been produced by chemical actions, in this vast magazine of matter, than that any of the rarer minerals have been so produced.

XXXI. SILVER.

This beautiful substance has, like gold, been known from the earliest records of mankind. It exists in various ores and mineral species. It is found native, or in combination with gold, mercury, copper, lead, sulphur, arsenic, antimony, and most abundantly as a sulphuret, either alone or mixed with other sulphurets.

Silver is of a yellowish-white colour, and, when burnished, the most brilliant of all the metals, except polished steel. It is soft when pure, and may be cut with a knife. It is malleable and ductile in a high degree. In the former property, that of malleability, it is superior to all the metals except gold, and may be beaten into leaves of $\frac{1}{100000}$ part of an inch in thickness. It is so ductile, that it may be drawn into threads finer than the human hair. In tenacity, it is superior to gold, a wire of .078 of an inch in diameter being capable of sustaining a weight of 178.13 lb. avoirdupois. It fuses at a temperature of about 1873° F., and, on cooling slowly, may be crystallized, its crystalline form being the cube or octahedron. When exposed in the state of leaf, or fine wire, to a powerful voltaic action, or when acted upon by the oxyhydrogen blow-pipe, it burns brilliantly with a light-green flame, emitting bright sparks. It is not oxidated by simple exposure to the air, nor by being kept under water; but if it be exposed long in a state of fusion, it partially combines with the oxygen of the air; or if it be heated to redness in contact with glass or porcelain, it attracts oxygen, and forms an oxide which combines with the earthy matter of the glass or porcelain, forming an enamel. Silver, besides its chemical union with oxygen, absorbs, when exposed to heat, in the state of fusion, a

quantity of oxygen gas, which it gives back again in the course of becoming solid. The quantity of oxygen thus absorbed is sometimes 20 times or more the volume of the metal. The only pure acids known to act on silver, are the sulphuric, with the aid of heat, and the nitric. Nitrohydrochloric acid likewise acts on silver, but feebly.

The density of silver is from 10.474 to 10.542, and its combining weight is reckoned 108.3. It unites with oxygen, chlorine, sulphur, and other substances, and it forms alloys with the bodies of its own class.

Its protoxide combines with ammonia, forming a body of vast explosive powers. This dangerous substance, if even slightly pressed by a hard body, nay, touched by a feather when dry, will explode with frightful violence. The explosion is attributed to the reduction of the metal, by the combination of its oxygen with the hydrogen of the ammonia, and the evolution of nitrogen gas. But this scarcely accounts for the effect, and it may be doubted whether other decompositions do not take place. Compounds of the same nature are formed by combinations of the oxides of gold and platinum with ammonia.

Chloride of silver is remarkable for its susceptibility to the action of light, on which account it is employed to fix images on paper. This mineral is found in veins, and sometimes in beds.

Sulphuret of silver, formed by single equivalents of sulphur or silver, is isomorphous with a sulphuret of copper, and the two substances replace one another in certain native sulphurets. The sulphuret is the most important of the ores of silver. It is found almost always in veins in the older formations, the matter of the adjoining rock being frequently impregnated with the sulphuret.

Silver is very generally associated in the natural state with copper, antimony, and arsenic, members of the sulphur

group of bodies. It is frequently found along with lead, in the ores of which it is seen to be diffused in fine threads. It is found likewise along with mercury.

If the compositions indicated by the table were correct, silver would approach in composition to both mercury and lead. Thus,—

Silver,	.	.	$H^{24} C^{14} = 14 H C + H^{10}$
Mercury,	.	.	$H^{17} C^{14} = 14 H C + H^3$
Lead, .	.	.	$H^{19} C^{14} = 14 H C + H^5$

But, however this be, it is difficult to conceive that these bodies have not all been produced by similar agencies, causing chemical changes of the matter of the siliceous and other mineral substances in which they are found.

XXXII. MERCURY.

Mercury, associated in popular language with silver, as *argentum vivum*, or quicksilver, has been known from the earliest ages. It is found in several species of ore ; but that from which nearly all the mercury of commerce is derived, is the sulphuret, termed likewise cinnabar, from which the metal is obtained by easy means. The cinnabar is mixed with lime, or iron turnings, and exposed to heat in a species of oven or large iron retort. The sulphur combines with the lime or the iron, forming with them a sulphuret, and the mercury itself, which is volatile, then passes off, and is received under water.

Mercury is distinguished from all the metals by being liquid at common temperatures. It has a silver-white colour and great lustre. Its density is about 13.3. At somewhat less than 40° below the zero of F. it becomes solid, crystallizing in regular octahedrons. At the moment of congelation it contracts, its specific gravity increasing to about 14.5. When solid, it is malleable, and may be cut with a knife. It boils at the temperature of 662° , and by a continuance of the heat, may be all evaporated, and condensed again on a cool surface. The vapour of mercury is invisible like air, and highly elastic, and, like other gases, it is expansible in an indefinite degree by heat. If enclosed in a strong vessel, and exposed to a high temperature, it will burst the vessel with tremendous force. Mercury, if entirely pure, does not seem to be acted upon by the moisture of the air at common temperatures ; but if heated to near the boiling point, it absorbs oxygen, forming scales of red oxide, and, if exposed in the state of vapour to air or oxygen gas, it slowly combines with oxygen. It is readily dissolved by nitric

acid, but is not affected by hydrochloric acid, in which respect it approaches to the characters of silver.

Mercury, although obtained in the liquid form, may likewise be procured in the state of a fine powder, but it again assumes the liquid form on becoming dry. To obtain mercury in this form, equal weights of the crystallized hydrate of protochloride of tin, and chloride of mercury, are dissolved, the former in diluted hydrochloric acid, and the latter in hot water, and the solutions are mixed and stirred together. The mercury is liberated, the whole of the chlorine combining with the protochloride of tin, and forming bichloride, which remains in solution. So fine is the division, that the liberated mercury takes several hours to subside. Mercury then assumes the form of minute division, which silver and other metals under certain conditions assume.

Mercury combines with oxygen and chlorine, sulphur, phosphorus, and other bodies, and with the substances of its own class, forming the alloys termed amalgams. Its combining weight is generally reckoned 101.43, though many chemists double this number.

Mercury is almost equally related to the noble metals, gold and platinum, as silver, but, like silver, it exhibits relations with copper and lead. Like silver, copper, and lead, it has a strong affinity for sulphur, and it is chiefly in combination with this substance that it is found in the mineral state. The sulphuret exists in gneiss, and in beds and veins in later deposits, though in none later, it is believed, than in some shales of the older secondary formations. Mercury is thus one of those rare and beautiful substances, produced in the earlier periods of the globe, when conditions existed of heat and other agencies, which may well account for chemical changes, which we cannot now produce by art.

XXXIII. COPPER.

This metal exists abundantly and in various species of ore. It is often found native, but the ores which produce it most largely are the sulphurets, and in an especial manner, the sulphuret termed glance copper, and copper pyrites, which last is the most important of the ores of copper, and is a compound of sulphuret of copper and sesqui-sulphuret of iron. The smelting of copper is for the most part complicated and laborious. When the ore which is acted upon is copper pyrites, the end aimed at is to drive away the sulphur, and oxidate the iron. The latter oxide combining with silica, which is supplied from siliceous substances during the process, forms a silicate which can be removed, while the copper, by a complication of processes, is freed from the various substances with which it is associated, and at length obtained in a state of sufficient purity for ordinary uses.

Copper is of a fine red tint, and is the only one of the metals, except titanium, which possesses this colour. By burnishing, it acquires a high degree of lustre. Its taste is nauseous and styptic, and by rubbing or heating, a peculiar odour is produced. It is a very malleable metal, and may be hammered into leaves of considerable fineness. In tenacity it surpasses gold, platinum, and silver, and is inferior only to iron. A wire of .078 of an inch in diameter has been found to support a weight of 302.26 lb. avoirdupois. It is hard and elastic, and this property being possessed by some of its alloys, they are sonorous, and used as bells. Its crystalline form seems to be the octahedral. It fuses at a temperature of about 1996° F., and hence it is but a little less fusible than gold; and if the heat be increased, it is dissipated in white fumes. When exposed to a stream of the oxyhydrogen blowpipe, or to voltaic action, it takes fire, and burns brightly, emitting a lively green light. When exposed to the air of the atmosphere, it becomes gra-

dually tarnished, and at length is covered with a dark-green crust of hydrate of a carbonate of copper. It is not acted upon by water, unless air have access to it, and hence water may be kept in a copper vessel, except that at the surface a green crust is formed. Copper oxidates slowly in the air at common temperatures, but when it is raised to a red heat, it combines with oxygen quickly. When a plate of the metal is heated red-hot, it is covered in a few minutes with a crust, which separates in scales as the plate is allowed to cool; and any quantity of this oxide may be obtained by alternately heating the plate of metal and plunging it in cold water. When copper is heated below redness, its surface assumes finely variegated shades of orange, blue, and yellow, and in this manner thin plates of it are sometimes tinged for toys and rude ornaments. Nitric acid acts powerfully upon it, but it is scarcely at all affected by being boiled in hydrochloric acid.

Its specific gravity, when fused, is about 8.667, and when forged, 8.95. Its combining weight is generally reckoned 31.71, although many chemists, perhaps with better reason, reckon it double, 63.42. It combines with oxygen, chlorine, sulphur, and other bodies, and it forms, with the other metals, alloys, some of which are of great importance in the arts, such as brass and bronze.

Copper exists most largely in the natural state in combination with sulphur, but it is found also in combination with oxygen and chlorine, and forms various salts, constituting distinct mineral species. The most abundant salts of copper are the sulphates, produced by the decomposition of its sulphurets. The relations of copper with sulphur itself have been pointed out, and we are thus led to associate its production with that mighty volcanic agency, to which the production of sulphur may not unreasonably be ascribed. Be this as it may, copper is the production of an early period in the history of the globe, it being never found, it is believed, in more recent rocks than the earlier members of the carboniferous era.

XXXIV. ZINC.

The early nations of Europe were acquainted with a mineral, which, melted with copper, formed brass; but it is not known whether they were acquainted with the metal zinc in its separate state. It is first mentioned by Paracelsus in the 16th century. But there is reason to believe that it was, from early times, known to the natives of the East, and that they possessed the art of rendering it malleable. It is found in several minerals, but the ores which chiefly yield it are the native carbonates, classed under the common name calamine, termed by miners blende, or zinc-blende. The extraction of the metal from the first of these classes of minerals, is effected by heating the ore along with carbonaceous substances; and so likewise it is from the sulphuret, after the process of roasting, as it is termed, or exposing the ore to a low red heat. The clay pots, or crucibles, in which the smelting process is performed, are closed at the top, while through the bottom there passes an iron tube, the upper aperture of which is within the crucible, while the lower terminates just above a vessel of water. Through this tube the vapour of the zinc, with the other gaseous products, passes, and the zinc is condensed in the water. It is then melted, and, being cast into ingots, forms the zinc of commerce.

Zinc is a brilliant metal, of a bluish-white colour. Its structure is lamellated, and it is seen to be composed of thin crystalline plates adhering together. It is a somewhat hard metal, resisting the action of the file. When pure, it may be hammered into leaves at a low temperature, but the impure zinc of commerce is not malleable at a low temperature, nor until heated somewhat above 210° , when it be-

comes, to a certain extent, malleable and ductile ; but at 400° again, it becomes so brittle, that it may be pulverized. This property of becoming malleable and ductile at a certain temperature is taken advantage of in the arts to form it into plates, and draw it into wires ; and by a process of annealing and working which it then undergoes, it can be made to retain the malleability which it had acquired. Pure zinc, according to Mr Daniel, fuses at a temperature of 773° F. When fused in open vessels, it combines with the oxygen of the air, and is converted into white oxide of zinc, popularly termed flowers of zinc. When the metal is raised to a very strong heat, it takes fire, burning with a brilliant white flame, like phosphorus, and throwing off a vast quantity of light white flakes of the oxide. When heated to whiteness in close vessels, it volatilizes without change. Its density, when cast, is 6.862, and it increases by forging to 7.21. Its combining weight is reckoned 32.31.

Zinc is somewhat abundantly diffused in the mineral kingdom, and largely in combination with sulphur. Its ores are usually found associated with those of lead. It possesses various characters in common with bismuth, and other members of the sulphur group, but indicates an approach to iron, and the members more immediately connected with silicium and aluminum.

XXXV. CADMIUM.

Cadmium is a metal found associated in small proportion with zinc, and partakes of its properties. It was discovered in the year 1817 by Professor Stromeyer of Göttingen. He detected it in an oxide of zinc, prepared for medical use ; and it has since been found in several of the ores of zinc. It is a brilliant metal, of a bluish-white colour, resembling zinc. It is very malleable and ductile, so that it may be hammered and drawn into wires. It is flexible, and yields to the knife ; and, like zinc, tin, and lead, it stains paper or the skin. It fuses before it arrives at a red heat, and, in close vessels, volatilizes, condensing again in drops, and crystallizing as it cools. It is little changed by exposure to the atmosphere. When heated in the open air, it takes fire, like zinc, emitting fumes of an orange-coloured oxide. Its density after fusion is 8.064, and after being hammered, 8.694. Its combining weight is calculated to be 55.83.

XXXVI. TIN.

Tin, although far less abundant than copper, was, like it, known to the earliest nations. It occurs in two mineral species, the peroxide, called tin-stone or tin-ore, and the cupreous sulphuret, called tin pyrites, or bell-metal ore. It is from the first of these ores that nearly all the tin of commerce is derived. It occurs in veins, or disseminated in granite and the primary rocks. It is found in Cornwall, Saxony, Bohemia, Hungary, in the peninsula of Malacca, and in some parts of the Eastern Archipelago, and especially in the island of Banca. In Cornwall, this ore occurs either in veins, or as rounded grains amongst beds of sand and rolled materials deposited by the action of water; the former yielding the block tin of commerce, which is the least pure, the latter, the grain tin, which is the most free from mixture. The smelting of tin is, like that of copper, a tedious process of art. The ore is first ground and washed, by which the heavier tin is separated from several of the lighter ores with which it is mixed. It is then exposed to the heat of a reverberatory furnace, when the sulphur and arsenic are expelled from the substances with which they were combined, by which means these substances are rendered so much lighter, that they may be separated by washing. The ore is then fused with lime and coal, by which process the lime combines with the earthy matters, and the coal reduces the oxide of tin to the metallic state.

Tin possesses considerable lustre, and a colour approaching to that of silver, but on exposure to the air, its surface becomes tarnished. It has an unpleasant taste, and, like copper, emits a peculiar odour when rubbed. It is soft and flexible, and, when bent backwards and forwards, produces

a crackling sound. It has considerable malleability, and is beaten for certain purposes of the arts, into leaves, termed tin-foil, of about $\frac{1}{1000}$ th part of an inch thick. When at the temperature of boiling water, it can be drawn into wires of considerable fineness. But it is inferior in tenacity to other of the more perfect metals, a wire of .078 of an inch in diameter being capable of supporting a weight of only 34.7 lb. It fuses at a temperature of 442° F.; but a violent heat is required to raise it in vapour. When heated to whiteness it takes fire, and burns with a white flame, very much like antimony, being converted into the peroxide, which may be obtained in octahedral crystals. Tin, though soon tarnished when exposed to the air, does not undergo much further change, and is not even sensibly affected by being kept under water, and hence its use in culinary vessels, as a coating to the more oxidable metals. But when water is passed over a surface of red-hot tin, the water is decomposed and the tin oxidated, and when tin is exposed for a time to the atmosphere in a state of fusion, it is partially oxidated, and assumes irridescent colours in the manner of copper. The density of pure tin is about 7.3. Its combining weight is calculated at 58.92. It enters into combination with oxygen, chlorine, sulphur, arsenic, and other bodies, and with other metals forms alloys, some of which are of important uses in the arts. Its bisulphuret is a beautiful substance so like gold in appearance, that the alchemists termed it aurum musivum or mosaic gold, and, as if further to delude them, it was found to possess, likewise, the property of being soluble in no acid except aqua regia. Peroxide of tin resembles alumina, in forming insoluble compounds with colouring matters, so that it is employed in dyeing as a base or mordant.

XXXVII. LEAD.

Lead is one of the most plentiful of the malleable metals, and the knowledge of it, like that of gold, silver, copper, tin, seems to have been possessed in the infancy of human societies. Of the ores of lead mineralogists enumerate upwards of 30 species, many of them very beautiful. They are found usually in veins, in the primary, transition, and lower secondary formations. Of these ores, greatly the most abundant, and that from which nearly all the lead of commerce is derived, is the sulphuret, termed likewise galena or lead glance. From this ore the lead is obtained by the action of heat in a reverberatory furnace. The sulphur and the metal are both oxidated, and the sulphur is driven off as sulphuric and sulphurous acids. A portion of the sulphuric acid combines with the oxidated metal, and forms sulphate of lead, to reduce which quick-lime and coal are added during the process, the lime combining with the sulphuric acid, and the carbon of the coal abstracting the oxygen of the oxide. The metal being reduced, is collected in vessels, from which it is cast into ingots, which form the subject of commerce.

Lead possesses a bluish-gray colour, and when newly melted or recently cut, is very bright, but it becomes tarnished by exposure to the air, its surface becoming oxidated, and the oxide combining with the carbonic acid of the atmosphere. Lead has little taste, but emits a peculiar smell on being rubbed, and it stains paper and the skin of a bluish colour. It is a soft metal, very flexible and inelastic. It is exceedingly malleable, and may be reduced to thin plates, by pressure or the hammer. It may be drawn into wires, but its ductility is not very great, and its tenacity is less

than that of any other of the ductile metals, a wire of $\frac{1}{10}$ of an inch diameter being capable of supporting only 18.4 lb. It fuses at the temperature of 612° , contracts on becoming solid, and if slowly cooled, forms octahedral crystals. It may be heated to whiteness in close vessels, without subliming. When exposed to the air, it becomes quickly tarnished by the oxidation of the metal, but the oxide further combines with carbonic acid, which preserves the metal for a long time from the further action of the air. At a high temperature, however, lead absorbs oxygen quickly, and when kept in a state of fusion, its surface is covered with a gray film; and when strongly heated, it is dissipated entirely in fumes of the protoxide. Water has, of itself, no action upon lead, but its presence facilitates the action of air in corroding it. In distilled water, and in close vessels, lead suffers no sensible change; but in open vessels it is oxidated, yielding minute white crystalline scales of carbonate of the protoxide.

The specific gravity of lead is 11.357, and it is not increased by hammering. Its combining weight is calculated at 103.73. It combines with oxygen, chlorine, sulphur, and other bodies, and it forms alloys with the other metals.

This metal although found only in the older rock formations, yet in its abundance, exhibits an approach to iron and the metallic bases generally diffused. It is found chiefly as a sulphuret, but largely too as a carbonate, and its salts form numerous mineral species.

XXXVIII. COBALT.

Cobalt is contained in minute quantity in aërolites. The ores of the metal are few, and, like nickel, it occurs for the most part associated with arsenic and sulphur. The ore from which it is usually procured is a native arseniet. It may be extracted from this substance by a process analogous to that employed in the case of nickel. It may be procured in the state of powder, and by the action of intense heat be fused into a mass. It is of a reddish-gray colour, and feeble metallic lustre. It is a brittle metal, and fuses at a heat somewhat lower than iron. It has hitherto been supposed to be magnetic ; but M. Faraday states that, when perfectly pure, it is not susceptible of this property. It is little, if any thing, affected by exposure to the air ; but it attracts oxygen when heated in open vessels, and at a red heat decomposes water. It has the property of communicating a colour, generally blue, to many of its compounds. Its density is about 7.834, and its combining weight is calculated at 29.57. This metal is manifestly allied, in its essential characters, to nickel and iron.

XXXIX. NICKEL.

This metal is found in a few minerals, and chiefly in combination with sulphur and arsenic. It is derived, too, from those remarkable metallic substances termed *aërolites*, which, from time to time, have fallen from the atmosphere, sometimes in masses of prodigious weight, and which have at all times excited, by their appearance, the wonder of mankind. A remarkable circumstance attending these bodies is, their uniform composition, denoting a common origin in them all. Many hypotheses have been formed to account for their origin and fall. The most probable is, that they are the result of some vast electric action, by which the elements of bodies already existing in the atmosphere, have formed new combinations. If metallic matter is formed of simpler elements, as is now contended for, we may conceive, perhaps, how a power as intense as the electricity of the clouds has been able to fix these elements in new combinations. All the *ærolites*, it is believed, contain nickel along with iron.

Nickel is generally obtained from the native arseniet of nickel, which is found both in the primary and older secondary rock formations, and from an arseniet obtained in the smelting of cobalt. The process is very complicated ; but the result is, that an oxalate of nickel is obtained, and that from this salt the oxalic acid is expelled by heat and the action of carbon, and the metal obtained in the form of an ash-coloured powder, which fuses at a high temperature.

Nickel is of a fine white colour, intermediate between silver and tin. It is somewhat softer than iron. It is malleable, and may be hammered into plates, not exceeding $\frac{1}{100}$ part of an inch thick. It is ductile, and may be drawn

into wires. It is attracted by the magnet, and, like iron, may be rendered magnetic. It is very infusible. It is not altered by exposure to the air at common temperatures, but at a red heat it is oxidated, and at the same temperature decomposes water. Its specific gravity, after being melted, is 8.279, and after being hammered, 8.932. Its combining weight has been computed to be 29.62. All the characters of this metal connect it with iron ; and if our hypothesis be correct, it only differs from iron in containing 2 more equivalents of hydrogen ; and this, it will be admitted, is a more probable hypothesis than that it is a distinct substance, formed of simple particles proper to itself.

XL. IRON.

Iron is, of all the metals which have been referred to, that which is the most generally diffused, and the most important in its uses. It forms a part of all the great masses of rocks and mineral deposits which form the solid crust of the globe. It is found in the water of rivers and the ocean, and it forms a constituent part of most animal and vegetable substances. It is found in small quantities native, but it is almost always in combination with oxygen, sulphur, silica, and other substances. The minerals which yield it in such quantity as to be termed ores of iron, are very numerous ; but those from which the greater part of the iron consumed in the arts is derived, are two,—black magnetic iron ore, and clay iron-stone. The former, a combination of the protoxide and peroxide of iron, occurs in beds, or single crystals, in the oldest rock formations, and it is from it that the purest of the iron of commerce is derived. Clay ironstone is essentially a carbonate of the protoxide, and occurs in veins in the primary formations, frequently along with ores of lead and copper, and very largely in the deposits of the coal formation, from which source the greater part of the immense consumption of Europe is supplied. The general method of smelting iron consists in exposing the ore to a powerful heat, along with carbonaceous matter and lime, in a large furnace. The carbonaceous matter, usually coke or charcoal, but now frequently common coal, acts by depriving the iron, brought to the state of an oxide by heat, of its oxygen, while the lime combines with the foreign matters of the ore, and forms a fusible compound termed slag. The particles of melted metal descend by their greater density to the bottom of the furnace, while the slag floats

upon the surface, and protects the metal from the action of the air. The slag runs out at an aperture in the side of the furnace, while the melted iron is let off by a hole at the bottom, plugged with sand or clay. Fresh matter being constantly supplied to the furnace, the process of fusion goes on continually. The liquid metal is received from the furnace in moulds of sand, and then forms the cast-iron of commerce. The substance thus obtained is an impure iron, but largely used, and of vast importance in the arts. It contains carbon, oxygen, and other foreign bodies. It is to free it from these, and convert it into what is termed soft or malleable iron, that it is subjected to a further process of purification. This consists in again fusing it in a peculiar kind of furnace, in contact with carbonaceous matter. The melted metal thus obtained, technically termed fine metal, is broken in pieces, and placed in a reverberatory furnace, where it undergoes the operation of puddling, which consists in stirring the metal, while semi-liquid, in the furnace, by which means a large disengagement takes place of carbonic oxide, which burns with a blue flame. The metal is next formed into balls and forged, which may be done by heavy hammers, but which, on the great scale, is effected by passing the metal, while hot, through a series of grooved rollers. The metal in this state, is termed mill-bar iron. It is then subjected to a further operation, which consists in welding pieces of it together, from which it derives its properties of more perfect malleability, ductility, and cohesiveness. It is now the bar-iron of commerce.

The iron thus procured contains a small proportion of carbon, and traces of silica and other substances. It may be rendered pure by bringing it to the state of an oxide, and then exposing it, at a red heat, in a tube of porcelain, to a current of hydrogen gas, by which means the oxide is

reduced, and the metal obtained in the form of a porous spongy mass.

Iron in its compact state, has a peculiar gray colour, known familiarly as iron-gray. It possesses the metallic lustre, and when polished exhibits considerable brilliancy. It has a styptic taste, and when rubbed emits a peculiar odour. It is malleable at every temperature, and its malleability increases with the degree of heat, and when heated to redness, it is so soft and pliable that it may be hammered into any form. It then, too, acquires the property of becoming so soft, without being fused, that it can be welded, that is, pieces of it may be united together by hammering or pressure. This property, so valuable in the arts, is possessed likewise, it has been seen, by platinum, though in a far inferior degree. Iron, although malleable, is less so than gold, silver, or copper. It is very ductile, and may be drawn into wires as fine as a human hair. In tenacity it exceeds all the metals, a wire of .078 of an inch supporting a weight of 449.34 lb. avoirdupois.

Pure iron is exceedingly infusible. The melting point of cast-iron is 3479° F., but that of malleable iron is much higher. In cooling it expands, and like the other metals tends to crystallize. When kept for a time at a red heat, it often forms large cubical or octahedral crystals, and the metal becomes brittle. When exposed to the air in which any moisture exists, its surface is speedily covered with the brown powder known by the name of rust; but if the air be perfectly dry, the iron is not acted upon. It is believed that in the rusting of iron, carbonate of the protoxide is first formed, and that this gradually passes into hydrate of the peroxide, the carbonic acid being evolved. It is remarkable that this rust of iron always contains ammonia, and that the native oxides likewise contain the same substance. When iron is heated to redness in the open air, it

is oxidated, and when inflamed in oxygen gas, it burns with brilliant sparks, the oxide in either case being fused. If the vapour of water be passed over it in a heated state, it decomposes the water by the abstraction of its oxygen. When in the state of minute division in which it is obtained by reduction of its oxide, it takes fire spontaneously in the open air.

Iron possesses the property of being attracted by the magnet, and it then becomes itself magnetic by induction, but if perfectly pure it instantly loses its polarity when the magnet is withdrawn. If it contains carbon, as in the case of steel or cast iron, it may become permanently magnetic. This property may be communicated by friction with the native loadstone, or with a bar of steel already magnetic, or by percussion, or by the electric shock, nay, by the body being placed for a sufficient time in a given position inclining to the horizon. The magnetic property is possessed by the black oxide, popularly termed the loadstone, and by the corresponding sulphuret.

The specific gravity of iron is about 7.7, with a slight variation dependent on the degree in which it has been hammered or compressed. By fusion its density is increased to 7.8439. Its combining weight is usually calculated at 27.18.

Iron forms with oxygen two well known compounds :—

- | | | | |
|---------------------------------|---|-----------------|------------------|
| 1. Protoxide, or ferrous oxide, | . | Fe | O. |
| 2. Peroxide, or sesqui-oxide, | . | Fe ² | O ³ . |

The black oxide or magnetic iron ore being
a compound of these two, namely, Fe O + Fe² O³.

The peroxide and its compounds are isomorphous with alumina and its compounds, and in other respects are very analogous to the aluminous compounds in their properties.

Iron, with respect to its abundance in the mineral king-

dom, approaches nearer than any of the metals which have been mentioned, to those metallic bases which form the great mass of the crust of the earth, silicium and aluminum. It is found everywhere associated with them, sometimes in veins traversing the older rocks, sometimes in beds manifestly deposited from a fluid medium, sometimes in nodules imbedded in deposits of clay, and sometimes in combination with other substances, in the crystalline state. It has been everywhere mingled with the matter of the soil, from which it is taken up by the roots of growing plants; and sometimes it is deposited by them again, as in bog-iron ore, in such quantity as to form considerable deposits, even in the newest formations.

XLI. MANGANESE.

This metal is widely diffused, existing in the organic as well as in the mineral kingdom, and the ores which contain it are numerous. Some of these are binary combinations of manganese with another body, as oxygen, and some of them are salts, having an oxide of manganese for the base, or part of the base. Of these ores, the most abundant are the oxides. From these the metal may be obtained by forming the oxide into a paste with oil, and exposing it to a violent heat in a covered crucible lined with charcoal, by which process several times repeated, the metal is de-oxidated, and remains in the crucible in the form of a semi-globular mass.

Manganese thus obtained, has a grayish-white colour somewhat lighter than cast iron. It is hard and brittle, so that it may be reduced to powder. It is doubted whether it is attracted by the magnet, when perfectly pure. It requires for its fusion the most intense heat of a wind furnace. It soon oxidates on exposure to the air, and when heated to redness attracts oxygen rapidly, the result being the protoxide. At common temperatures it decomposes water, though slowly, but at a red heat the decomposition is very rapid.

The specific gravity of this metal has been variously computed from 7.05 to 8.013. Its combining weight has been computed to be 27.72 or nearly that of iron. It has some of the characters of zinc, but all its essential properties connect it with iron.

Iron and the allied substances exhibit an increasing affinity for oxygen over the bodies that precede them. They pass into the next group to be considered, of which the

type is aluminum, and which latter metals have a yet increased affinity for oxygen, and are never found in nature pure. They form the basis of the earths, commonly so called, and pass into the bases of the alkaline earths, and these again into the bases of the true alkalies, which have the greatest affinity of all known bodies for oxygen.

None of these groups of bodies, however, is unconnected with another, nor can they be represented in a strictly linear series. They rather form reticulations than chains. Tracing, indeed, a series of bodies from nitrogen downwards, we find the connexion wonderfully perfect; but this series is not insulated but passes into others. We have the sulphur group passing gradually by antimony and bismuth into copper and the more perfect metals, and in like manner the siliceous group becomes connected with iron, but still more directly with aluminum, and the bodies we are now to review. These latter bodies arranged nearly in the order of their affinities for oxygen, are—

- | | |
|--------------------------|--------------|
| 1. Cerium and Lanthanum. | 4. Aluminum. |
| 2. Thorium. | 5. Yttrium. |
| 3. Zirconium. | 6. Glucinum. |

Aluminum is the type of the series, and the others, all rare bodies in nature, are chiefly interesting as shewing the passing of aluminum, on the one hand, into the iron series of bodies, and on the other into the bases of the alkaline earths.

XLII. CERIUM AND LANTANUM.

Cerium was first obtained from a mineral, found in the copper mine of Bastnäs, in Sweden, and it has been found in one or two other rare minerals, derived from the north of Europe and Greenland. It exists in the natural state only as an oxide, always associated with silica, alumina, yttria, and other substances. It may be obtained by forming a chloride of cerium by the same process as is employed in the cases of aluminum, glucinum, and yttrium, to be referred to. It is procured in the form of a gray powder, having a metallic lustre. Its properties may be said to be unknown. Its oxide resembles the earths, commonly so called, and it is manifestly in the same class of natural bodies.

Lanthanum has been recently added to the list of simple bodies, by the discovery of its oxide in the same mineral from which oxide of cerium was first procured. Nay, it appears that this new oxide forms two-fifths of what was regarded as oxide of cerium, so that the cerium, hitherto described as a simple body, is really a compound one. The new element, it is said, alters little the properties of cerium, and therefore the former has been termed lanthanum, as being concealed, as it were, in cerium. It is described by M. Mossander, its discoverer, as being a gray powder with metallic lustre, which undergoes oxidation in water, and is changed into a white hydrate.

Now, nothing can be less satisfactory than these experiments, in so far as they are designed to establish the existence of a new body, to be termed simple. The intimate alliance of this rare substance with another from which it can scarcely be distinguished, should refer us to some common origin for both, rather than to a distinct origin for each.

In truth, the two bodies are so similar, that it is almost ridiculous to regard them as essentially and radically distinct from one another. We frequently find a much greater difference in the characters of the same body under different circumstances, than in those which we thus assume to be distinct. Shall it be said, that having been unable to decompose the metallic base of lanthanum, we are bound to hold it to be simple? Such a conclusion should of itself shew that our rule is unsound. The negative evidence that a substance so rare as lanthanum has not been decomposed, and is therefore to be regarded as simple, cannot, it is manifest, be weighed against the evidence supplied by analogy, that such a substance must be derivative and not simple. The discovery of twenty such substances, instead of shewing that twenty new elements should be added to the list of simple bodies, should lead us to the conclusion, that the reasoning had been illogical by which so many had been already admitted.

XLIII. THORIUM.

This metal is derived from an earth, thorina, found in an extremely scarce mineral obtained from Norway. The earth itself is an oxide of the metal, and the metallic base is derived from it by a process similar to that pursued in the case of aluminum. The metal is obtained as a dark heavy powder, which, when pressed by the burnisher, exhibits a metallic lustre, and an iron-gray colour. It is not oxidated by water, whether hot or cold. When gently heated in the open air it takes fire, and burns with amazing brilliancy. The result is thorina, which is as white as snow, and exhibits no trace of fusion. The combining weight of thorium has been calculated at 59.83.

XLIV. ZIRCONIUM.

Zirconium, so named from zircon, a precious stone, derived from the Island of Ceylon, is found in the zircon, the hyacinth, and three other rare minerals. It may be procured by heating potassium with the double fluoride of potassium and zirconium. It is obtained as a black powder, which may be compressed by the burnisher into thin shining scales of a dark gray colour and faint metallic lustre. Its particles adhere so slightly, that it is incapable of conducting electricity. It is not oxidated by being boiled in water. When heated in the open air, it takes fire at a moderate temperature, burns brightly, and is converted into zirconia. Its combining weight is calculated at 33.67.

XLV. ALUMINUM.

Aluminum is derived from the oxide, alumina, a substance, which, along with silica, forms the greater part of the solid crust of the globe. The oxide forms the basis of numerous mineral species, generally as a base, but often as an acid, and some of them amongst the most beautiful of the mineral kingdom, and only surpassed, if they can be said to be surpassed, by the diamond. The metal itself may be obtained by heating the oxide to whiteness, and passing through it the vapour of potassium. But it is best obtained by the action of potassium on chloride of aluminum. Minute pieces of potassium are put into a crucible of porcelain or platinum, over which is placed a quantity of anhydrous chloride of aluminum, containing as nearly as possible, the quantity of chlorine equivalent to the potassium employed. The lid of the crucible being fixed down, the crucible is heated. At the moment of decomposition, an intense heat is evolved, which raises the crucible to redness in an instant. The matter within the crucible is fused, and when quite cold, it is plunged into a vessel of water. The potassa is dissolved, and there is found in the solution, a gray powder, which, when closely viewed in the sunshine, is seen to consist of minute metallic scales. These being washed in cold water are filtered and dried. When this scaly powder is pressed by a burnisher on a hard substance, as steel, or in an agate mortar, the particles are partially welded together, and form a substance which strongly reflects the light. Aluminum thus obtained, resembles the noble metal platinum under the same circumstances. In this state of minute division, it is a non-conductor of electricity, but becomes a conductor when fused.

Aluminum requires an intense heat to melt it. It is not liquefied at the temperature at which cast-iron melts, and its precise point of fusion is unknown. When heated in the open air it takes fire, and burns with a brilliant light, producing alumina; and if the combustion be in oxygen gas, the flame is splendid, and the heat excited so intense as partially to fuse the earth, although one of the least fusible substances in nature. When heated in chlorine gas, it in like manner takes fire, and is converted into chloride of aluminum.

Aluminum, although it has a powerful affinity for oxygen, is not readily acted upon by exposure to the air. It is not oxidated by water at common temperatures; but when the water is raised to the boiling state, a slight oxidation is seen to commence.

The combining weight of aluminum is generally estimated at 13.72; but some reckon it double, and others reduce it to 10.

The most important of the compounds of aluminum, and one of the most generally diffused products of the mineral kingdom, is the oxide. This substance is hard, and infusible in an extraordinary degree. It is found nearly pure in the class of gems comprehended under the term sapphire, namely, the sapphire proper or blue sapphire, the ruby, the topaz, the emerald, the amethyst. It is itself obtained as a white powder, destitute of taste and smell, and only fusible at an intense temperature. It is insoluble in water, although under certain conditions it combines with water, forming hydrates. These hydrates are with difficulty soluble in water, and the solution, when condensed, produces a gelatinous mass, like hydrate of silicium under the same circumstances. Alumina unites with acids as a base, forming salts, though it does not perfectly neutralize them, but it has likewise feeble acid powers combining with earthy

and alkaline bases. In the feebleness of its acid properties it resembles silica, as it does likewise in its external characters, in its infusibility, in its insolubility in water (with the power, however, of combining with that body), and in the hardness which it communicates to the minerals in which it exists.

Silica and alumina exist associated together throughout the entire mineral kingdom. They form the basis of what are termed clays, in which the silica stands to the alumina somewhat in the relation of an acid to a base. They form the bases, further, of all the larger masses of mountain rocks, and great mineral deposits, along with magnesia, lime, and the other alkaline earths and alkalies, together with the oxides of iron and other substances. It is not without seeming reason that the ancients reckoned earth one of the pristine elements of nature. They supposed all metals and precious stones to be derived from it, all plants and even animals; and science may yet admit, that metals and precious stones are derived from the elements which constitute earth, and that the matter of plants and animals has no other origin.

XLVI. YTTRIUM.

This substance is the metallic base of an earth obtained in 1794, from a solitary mineral species found in the quarry of Ytterby, in Sweden, and since discovered in a few other minerals equally rare. The earth is an oxide, from which the metallic base is derived by the same process which has been described in the case of aluminum, that is, the chloride of the metal is subjected to the action of potassium. The metal is obtained in the state of minute scales, having the colour of iron, and a lustre much inferior to aluminum. It is brittle, whereas aluminum and glucinum are ductile. At common temperatures it does not become oxidated in the air or in water. When heated to redness it takes fire, and is converted into yttria, and in oxygen gas the combination takes place with surpassing splendour. Its combining weight is estimated at 32.25, though considerable doubt exists as to the true proportion.

XLVII. GLUCINUM.

This metal is derived from the earth glucina, which is an oxide of the metal. This oxide has only been found in a few rare minerals, of which the principal are the emerald and the chryso-beryl. The metallic base is best derived from the metal brought to the state of chloride, and the process for obtaining it is precisely that used for obtaining aluminum. Small pieces of potassium are put into a crucible of porcelain or platinum, and over this an equal bulk of chloride of glucinum. The lid of the crucible being fixed down, a spirit lamp is applied, when decomposition takes place, the crucible becoming red hot. The mass in the crucible is suffered to cool, and then immersed in water, by which means the chloride of potassium is dissolved, and the metal obtained, by filtration, in the state of a dark ruby-coloured powder.

Thus glucinum is obtained by the same process, and presents the same external characters, on being reduced, as aluminum. When the scaly matter is burnished, it acquires metallic lustre. Although, having a powerful affinity for oxygen, it may be exposed to air or moisture, or be even boiled in water without being oxidated. When strongly heated in the open air it takes fire, and burns with a vivid flame, and when the combustion takes place in oxygen gas, the splendour of the light is very great. The product in either case is the earthy oxide, which is not at all fused by the intensity of the heat evolved.

Glucinum combines with oxygen, chlorine, and other bodies, in the manner of aluminum, and forms alloys with several of the metals. Its combining weight has been estimated by some at 26.54, by others at 17.7.

XLVIII. MAGNESIUM.

Magnesium is derived from the oxide. The metal being brought to the state of chloride, is acted upon by potassium, which combining with chlorine, leaves the magnesium free, in the same manner as in the process for obtaining aluminum. The metal had been before obtained by Davy, by means of voltaic action, in one of that series of brilliant experiments which proved so many bodies to be compound, which for ages had been deemed simple. It was first obtained by means of heat and chemical affinities alone by M. Bussey, in the year 1830. Five or six pieces of potassium of the size of peas were put into a glass tube, closed at one end, and bent so as to form a little retort. Upon the pieces of potassium were laid fragments of chloride of magnesium, and these being heated to near the point of fusion, a lamp was likewise applied to the potassium, and its vapour transmitted through the heated chloride. Vivid incandescence took place, and on dissolving the mass, after being cooled in water, the chloride of potassium, with any remaining portion of chloride of magnesium, was dissolved, the pure magnesium subsiding.

This substance possesses a bright metallic lustre, and resembles silver. It is malleable, and fuses at a red heat. In moist air it oxidizes superficially, but undergoes no change in air which is dry, and may be even boiled in water without being oxidated. When strongly heated in air it burns brilliantly, and yields magnesia, and in chlorine gas, it takes fire spontaneously.

Its specific gravity has not been ascertained, but it is heavier than water, sinking quickly in that liquid. Its combining weight was estimated by Berzelius at 12.69.

No subsequent experiments have either proved or disproved the conclusion of the illustrious Swede, yet I cannot but believe that the combining weight of magnesia must exceed 15, so that it may comprehend all the elements which are assumed to enter into the combination of the nearly allied metal calcium.

Of the compounds of magnesia, one, the oxide, enters into the composition of the larger earthly deposits of the globe, and of numerous mineral species, as the precious serpentine, the chrysolite, epsom salt, meerschaum, amianthus, &c. In its separate state, it is an earthy white powder, destitute of taste and smell. It possesses the alkaline property of combining with acids, and producing neutral salts, but it has less action on vegetable colours than the other alkalies, arising, it may be believed, in part from its greater insolubility. It is exceedingly difficult of fusion, having only yet yielded to the flame of the oxyhydrogen blow-pipe, by the action of which it is converted into a white enamel. It is very sparingly soluble in water, and, like lime, is more soluble in cold water than in hot. It seems to be intermediate in its characters between the oxides of alumina and lime, and it has some relations with silica, with which it enters into combination, and with which it is widely associated in the natural state.

XLIX. CALCIUM.

Lime, so largely diffused over the mineral kingdom, was, like the other substances, termed earth, shewn, by the admirable researches of Davy, to be a metal, to which he applied the term calcium. He obtained it by forming the carbonate of the oxide into a paste with water, which he placed upon a disc of platinum, connected with the positive pole of a galvanic battery, while, in the hollow of the paste, he placed a globule of mercury connected with the negative pole. The oxygen of the oxide appeared at the positive pole, while the calcium appeared at the negative, and formed an alloy or amalgam with the mercury; and this being exposed to heat, in the vapour of naphtha, the mercury was volatilized, and the calcium left behind. This method was subsequently improved, but still the quantity of metal obtained has been very small.

Calcium evidently possesses the general characters of the class of metals to which it belongs. It is white, like silver, and highly combustible. When exposed to the air, it attracts oxygen so strongly, that, in a few minutes, it is converted into the oxide, and, when heated, it burns, and lime is in like manner produced. Its combining weight is calculated by Berzelius at 20.52, by Dr Thomson at 20.

It combines with oxygen in two proportions. The protoxide has so great an affinity for acids, that it exists native only in combination with them. Of these salts greatly the most extended is the carbonate, which exists throughout the organic and inorganic kingdoms, forming, in the latter, vast mineral deposits, and entering into all the great series of rock formations. The oxide itself is a white powder, similar in external characters to the corresponding oxides of

the metallic bases of the earths and alkalies. It has an acrid taste, and the characters termed alkaline, in changing vegetable blues to green, and then to yellow. It is amongst the least fusible of known bodies, yielding only, if it yields at all, to the most powerful heat of the oxyhydrogen blow-pipe, when it melts into a white enamel. When heated to redness, it becomes vividly phosphorescent. It has a great affinity for water, combining with it in a definite proportion. But it is very sparingly soluble in that liquid, and more soluble in cold water than in hot. It may be regarded as intermediate in its characters between magnesia and the alkalies, and seems to have certain relations with silica, with which it is everywhere associated in the mineral kingdom.

L. STRONTIUM.

Strontium is the metallic base of the earth strontia, or strontites, and may be obtained from the carbonate by the same process as is employed for obtaining calcium. It may be produced, likewise, by passing the vapour of potassium over strontites heated to redness. The metal obtained is heavy, white like silver, and fusible with difficulty. When exposed to the air, or thrown into water, it is quickly oxidated, and converted into strontites, which is a protoxide of the metal.

Its combining weight has been calculated by Berzelius at 43.85, by Dr Thomson at 52.07.

Like lime, it combines with oxygen in two proportions. The protoxide is the earth strontites, which occurs in a few rare minerals, of which one is the green carbonate found in the lead-mine of Strontian, in Scotland. The oxide is nearly, if not altogether, infusible, and is acrid in taste, and strongly alkaline. It has a great affinity for water, though it is little soluble in that liquid. When exposed to the air, it attracts water, with which it combines in a definite ratio, swelling and crumbling into powder, like lime under the same circumstances, and evolving much heat. This substance is therefore altogether similar in its characters to lime, and the metallic bases of both must be regarded as in the same class of bodies.

LI. BARIUM.

Barium is derived from the protoxide barytes. It has as yet been obtained only in minute quantity, by the powerful action of galvanism. It is a dark-gray substance, less bright than cast-iron. It fuses at a heat below redness, and produces a vapour which acts strongly upon glass. It has a strong affinity for oxygen, attracting it from the air, and from water. When heated, it burns with a deep red light. Its density has not been determined. Its combining weight, as calculated by Berzelius, is 68.66.

Like calcium and strontium, it combines in two proportions with oxygen. The protoxide occurs in a few minerals chiefly found in lead-mines. It is a grayish-white powder, of specific gravity about 4. It has a caustic alkaline taste, converts vegetable blues to green, and neutralizes the strongest acids. It is insoluble in alcohol, and fuses only at a very high temperature. It has a strong affinity for water, but it is less soluble in that liquid than soda and potassa. If exposed to the air, it immediately attracts moisture, swells out with evolution of heat, and crumbling into powder, in the manner of quicklime and barytes, after which it gradually attracts carbonic acid, and loses its acid properties, in the same manner as quicklime and strontites, under the same conditions. If, in place of this slow absorption of water, the liquid be added in quantity, the barytes in like manner combines with it, and swells and crumbles down, with the evolution of so great a heat as to become luminous. In either case it combines with water in the proportion of 1 equivalent, and forms a hydrate. This hydrate is a white substance, fusible at a red heat, and capable of sustaining the highest temperature of a forge without parting with its water. It has the caustic and alkaline properties of the anhydrous protoxide. These characters indicate, beyond all question, the close relation between calcium, strontium, barium, and their compounds.

LII. LITHIUM.

This metal is derived from the alkaline earth, which is an oxide of the metal, found in mica, and some rare minerals. Davy, by means of a voltaic battery, extracted from this alkali, the metallic basis, which he termed lithium. It is a white-coloured metal, resembling sodium and potassium, but possessing so powerful an affinity for oxygen, and attracting it with such rapidity, that it has scarcely admitted of examination in its separate state. Its combining weight was calculated by Berzelius at 6.44 ; by Arfwedson at 10.247. It is probable that neither is correct, and that the combining weight of lithium approaches nearer to that of the alkalies, which it resembles in all its other characters.

Its only known compound with oxygen is lithia. This substance has been hitherto derived from a few minerals, as petalite, spodumene, the tourmaline, and some varieties of mica ; and it has been found in the mineral waters of Carlstadt in Bohemia. It is best prepared from petalite and spodumene, in which two minerals it exists combined with silica and alumina. It has a white colour, and a taste acrid and caustic in a high degree. It forms with water a hydrate, like soda and potassa. At a red heat it melts, forming a transparent liquid. When exposed to the air it attracts carbonic acid, and is converted into a carbonate. Its solubility in water is less than that of soda and potassa, and when exposed to the air, it does not like the latter become deliquescent. It is scarcely soluble in alcohol, and if that substance is added to an aqueous solution, the lithia, after an interval of some hours, is precipitated. When heated in a platinum crucible, it acts with force upon the metal.

LIII. SODIUM.

Sodium, the metallic basis of the alkali, soda, was obtained by Davy only a few days after his memorable discovery of the composition of potassa. It was obtained by the action of a powerful voltaic battery on hydrate of soda, by means similar to those employed for obtaining the same class of metals. But the metal may now be obtained in any quantity by heat and chemical affinities alone, by mixing the carbonate, but better and more safely, the hydrate, with charcoal and iron-filings, and exposing the mixture to a powerful heat.

The metal is of a bright silver-white colour, and is lighter than water, having at 59° F. a specific gravity of 0.972. At the temperature of 32° , it is malleable and soft, and it becomes gradually softer by the increase of heat, and at 184° it fuses, becoming entirely liquid. At a red heat, and in the absence of atmospheric air, it rises in vapour unchanged. It is oxidated when exposed to the air at common temperatures, but very slowly if the air be dry. When heated, however, in the air, it is rapidly oxidated, and when the heat is increased, it takes fire and burns with a bright yellow flame. When thrown into water, it is in like manner rapidly oxidated, hydrogen gas being evolved. It rolls about upon the surface with a hissing noise; but if fixed to a spot, by rendering the water viscid, it takes fire; and when a few drops only of water are thrown upon it, it evolves so much heat as to be kindled.

Its combining weight has been estimated at 23.31. It combines with oxygen in at least two proportions, with chlorine, sulphur, and other bodies.

The protoxide forms the alkali soda. This substance

exists in vast abundance in the mineral kingdom, in animals, in marine plants, and in many vegetable tribes which grow on land. It may be obtained either in the anhydrous state or as a hydrate. In the former state it is a gray-coloured substance, exceedingly difficult of fusion. When it combines with an equivalent of water, it becomes white in colour, and more fusible than before. It possesses all the characters termed alkaline, in the first degree.

Chloride of sodium, forming the well-known substance common salt, is produced by the combustion of sodium in chlorine, in which the metal takes fire spontaneously, burning with bright sparks. It is produced, likewise, by heating sodium in hydrochloric acid gas, or by passing a current of chlorine gas over it heated to redness, or by dissolving soda in hydrochloric acid. But it is from sea-water that it is obtained in the largest quantity, by simple evaporation. It exists, likewise, in many saline springs; and is found in vast beds, chiefly in the new red sandstone formation, but occasionally, also, in the older deposits. It is of a white colour, and has a grateful saline taste. It fuses at a red heat without decomposition, and becomes a transparent mass on cooling. Its solubility in water is little affected by differences of temperature. It deliquesces slightly in a moist atmosphere, but suffers no change when the air is dry.

LIV. POTASSIUM.

Potassium was obtained by Davy in the first of those experiments by which the existence of the alkaligenous metals was made known. It may be derived from the alkali by voltaic action, or by heat and chemical affinities, in the same manner as the other metals of the class to which it belongs. It is best procured by distillation from a mixture of hydrate of potassa, charcoal, and iron filings.

The metal when newly cut resembles mercury in lustre and nearly in colour. At 32° F. it is brittle, and when broken exhibits a crystalline texture. By an increase of temperature it becomes malleable, and at 50° is so soft that it may be moulded by the pressure of the fingers like wax. By a further rise of temperature it becomes viscid, but is not entirely liquefied until the temperature reaches 150°. Atmospheric air being excluded, it volatilizes at a low red heat. It is the lightest of known metals, its density at the temperature of 60° being .865. It is, like sodium, a good conductor of electricity. It is rapidly oxidated in the air, becoming covered with a crust of potassa in a few minutes, on which account it is preserved in vessels from which air is excluded, or under fluids, such as naphtha, which do not yield oxygen. When heated in the open air it takes fire, and burns with a brilliant purple flame. It decomposes water the instant it touches it, and is itself set on fire by the heat evolved, burning brightly on the surface, while the hydrogen evolved is likewise set on fire. If plunged under water, a violent action in like manner takes place.

Its combining weight has been estimated at 39.26. It combines with oxygen, for which it has the greatest affi-

nity of any known substance ; with chlorine, sulphur, and other bodies, in the manner of sodium, forming analogous compounds.

Its protoxide, potassa, has been known and used in the arts from ancient times, and was familiar to the alchemists in their fruitless labours. But the alchemists mistook the hydrate for the pure alkali, and when they termed it the vegetable alkali, were ignorant of its existence in the mineral kingdom. It is found, like soda, in all the great rock formations, and forms the basis of numerous mineral species, chiefly along with silica, alumina, and other earthy bodies. In the anhydrous state it is a white solid, intensely caustic, and fusible at a temperature a little above that of redness, but capable of bearing the strongest heat without being decomposed or volatilized. It has a powerful affinity for water, and great heat is evolved during their combination. Water dissolves it in any proportion, but with the single equivalent, it forms the true hydrate : the excess may be driven off by heat, but the single equivalent which constitutes the hydrate remains so strongly combined, that it cannot be thus separated. This hydrate is solid at common temperatures, but fuses at a heat somewhat below redness, and in cooling assumes a crystalline texture. It has the essential characters of the anhydrous oxide, possessing the properties termed alkaline in the highest degree, and neutralizing the most powerful acids.

The chloride of potassium is similar to the chloride of sodium, and so it may be said of all the analogous combinations of the two metals which have been compared together. And not only are sodium and potassium thus closely allied in their properties, but they follow in a natural sequence the bodies which precede them. From magnesium, the gradations consist in an increasing affinity for oxygen, and a corresponding increase in the alkaline characters

of the compounds. Their oxides are all soluble in water, caustic and bitter, and they all act similarly upon vegetable colours, constituting a natural group as well defined as any in the mineral kingdom.

But these oxides are each composed of a metal combined with oxygen. There is, however, another body possessing the very same characters, and known from the earliest periods of chemical inquiry as an alkali ; but composed, not of a metal combined with oxygen, but of two other bodies, hitherto regarded as simple, combined with one another, hydrogen and nitrogen. This body is ammonia, the known composition of which proves, beyond dispute, the compound nature of the alkaligenous metals, and, consequently, of all the metals.

AMMONIA.

Ammonia is obtained by a well-known process from sal-ammoniac, which is regarded as a compound of hydrochloric acid and ammonia. The substance obtained from this salt has been proved, by synthesis and analysis, to be a compound of hydrogen and nitrogen, $\text{H}^3 \text{N}$. It is a colourless aëri-form fluid, having a peculiar and pungent odour. It is altogether irrespirable in the pure state, and can only be received into the lungs when largely mixed with air. It extinguishes the flame of burning bodies, and yet is itself slightly inflammable, for a small jet of it will burn in an atmosphere of oxygen gas, and when a lighted taper is immersed in it, the flame enlarges before being extinguished. When mixed with oxygen gas, it detonates by means of the electric spark, water being formed and nitrogen set free. At the temperature of 50° , and under a pressure of $6\frac{1}{2}$ atmospheres, it becomes liquid, and is then colourless and transparent, and of a density of about 6.76.

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This substance possesses the properties termed alkaline in a high degree. It affects in the same manner as the other alkalies the vegetable colours; it has the acrid taste which characterizes them, and, like them, it combines with acids, and neutralizes them.

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Ammonia has a powerful affinity for water. According to Sir Humphry Davy, water takes up 670 times its bulk of the gas, under a pressure of 29.8 of an inch, at 50°F. ; and under strong compression, or at a higher temperature, it absorbs a larger quantity. During this absorption heat is evolved, and a great expansion of the liquid takes place. In saturating with gas 6 cubic inches of water, Dr Thomson found that the water increased in bulk to 10 cubic inches.

The aqueous solution of ammonia possesses the taste, the pungent odour, and the alkaline properties of the gas. It enters into ebullition at the temperature of about 130° , and it freezes at nearly the same temperature as mercury.

The salts of ammonia are similar in their essential characters to the other alkaline salts, distinguished only by the results produced by the base of the one being volatile, and the other fixed. Thus none of the salts of ammonia can bear a red heat, without being dissipated in vapour, or decomposed. When the acid as well as the base is volatile, they both pass off together unchanged; but when the acid is fixed at a low red heat, then the ammonia alone is volatilized.

Now, here is a substance alkaline, in every sense of the word, associated with the other alkalies by characters and properties which connect it as closely to them as the species of any genus are related to one another. Can we believe that these substances, though represented by different chemical formulæ, are really different in their essential constitution? Are we not rather compelled to believe, that our chemical formulæ, whatever they be, must represent substances of a common nature? But ammonia is represented by H^3N , and the alkalies by MO , M representing the alkaligenous metal. We must therefore find a common expression for H^3N and MO ; and this we can only do by reducing them to a common root.

Now, H^3N , on the hypothesis $= H^3 + C O = H^3 + H^2 C^2 = H^5 C^2$. By the table, potassium $= H^{11} + C^2 O^2$, and potassa accordingly, $= H^{11} C^2 O^2 + O = H^{11} C^2 O^3 = H^{11} C^2 + H^6 C^3 = H^{17} C^5$; and upon the same principle sodium, $= H^{11} C^2$, and soda, $= H^{11} C^2 + H^2 C = H^{13} C^3$. We have therefore, as expressions for the three substances respectively,

Ammonia,	.	.	.	.	$H^5 C^2$
Potassa,	.	.	.	.	$H^{17} C^5$
Soda,	.	.	.	.	$H^{13} C^3$

The substances are therefore all derivable from common roots, and in this respect, there is no distinction between ammonia and the two alkaline bodies connected with it ; and further, there is no other hypothesis, except that of derivation from a common root, that will explain the identity of the essential characters of ammonia and the other alkalies.

Ammonia being formed by the combination of hydrogen and nitrogen, it may be expected that the elements of nitrogen will likewise exist in the alkalies. Accordingly, these alkalies comprehend the secondary root $\text{CO}=\text{N}$, and not only the alkalies, but all the alkaline earths, and all the metallic oxides. Finding, indeed, that nitrogen, or the elements of nitrogen, entered into the composition of ammonia, we might, *à priori*, have inferred that it entered into the composition of the alkalies ; and if into the composition of the alkalies, into the composition of all the bodies with which the alkalies are related, namely, the alkaline earths and metallic oxides : and the fact, that hydrogen and nitrogen can and do form a body similar to that which a metal and oxygen form, demonstrates that the same particles of matter are common to ammonia and the alkalies.

AMMONIUM.

When ammonia in solution in water is placed in contact with mercury at the negative end of a voltaic battery, and the circuit is completed, the mercury increases to about 5 times its former volume. The same effect is produced by using sal-ammoniac slightly moistened. A cavity being made in the sal-ammoniac, it is placed on a plate of platinum attached to the positive end of a battery, and there is placed in the cavity about 50 grains of mercury, which is brought in contact with the negative end of the same battery by a platinum wire. A strong action takes place, with effervescence and the evolution of much heat, and the mercury, in a few minutes, increases in the remarkable manner referred to. The resulting compound is a solid substance, of specific gravity below 3, having the entire appearance of an amalgam of zinc. At the temperature of 70° or 80° this substance is very soft; but at 32° it becomes a firm crystalline mass. When acted upon by water, the mercury is revived, and ammonia remains in solution. When put in a glass tube, or when confined under naphtha or oils, the mercury separates, ammonia is formed, and a quantity of hydrogen is evolved. From these, and precise experiments regarding the substances evolved, it has been inferred that ammonia, united to an additional equivalent of hydrogen, combines with the mercury, and forms this substance, which, in its combination with mercury, exhibits the characters of a metal.

But how can we suppose a metal to be formed by a combination of hydrogen with nitrogen? We cannot even imagine such a result, if we hold a metal to be a simple

body; but the seeming anomaly disappears, when we regard, as we must do, a metal as a compound body, derived from the same roots as ammonium.

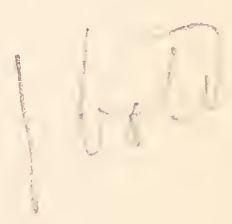
And, if one metal be formed by a combination of hydrogen with nitrogen, or the elements of nitrogen, we are bound to assume that all metals are so formed. For to hold that a single metal was formed by such a combination, and that the others were not, would be to violate every analogy founded on the physical and chemical characters of the bodies. If $H^4 N$ represents ammonium, we must find a common expression for all the bodies of the same class. But we can only find such an expression by referring them all to a common root; and, therefore, if ammonium be a metal, all the metals are compound.

Besides the compounds, ammonium, $H^4 N$, and ammonia, $H^3 N$, chemists have been led to the conclusion, that there exists another compound of hydrogen and nitrogen, $H^2 N$, to which has been applied the term amidogen. This substance, indeed, has not been insulated; but, from certain actions, its existence or formation has been inferred, and the investigations of Dumas, and more recently those of Rose and Kane, have seemed to give a considerable degree of probability to the theory. But the formation of amidogen may be maintained on other grounds than those that have been taken, namely the law of continuity, as applied to chemical combinations, to which I shall immediately refer. Every substance being assumed to be derived from a root in the ascending order, the more immediate root of the series of bodies, of which ammonium is a sequence, is $H N$, or, as it may be called, monohydruret of nitrogen, and the series of the bodies will be represented thus:—

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| 1. Monohydruret of nitrogen, | . | . | $H N$ |
| 2. Bihydruret of nitrogen, or amidogen, | . | . | $H^2 N$ |
| 3. Terhydruret of nitrogen, or ammonia, | . | . | $H^3 N$ |
| 4. Quaterhydruret of nitrogen, or ammonium, | . | . | $H^4 N$ |

The root H N corresponds with phosphorus, on the supposition that the combining weight of that body is 15.12, and that phosphorus, accordingly, is resolvable into H C O . It cannot be maintained that this actually is so, because we are in some doubt as to the true combining weight of phosphorus. But probabilities exist in favour of the opinion, founded on the analogy between phosphorus and the ammoniacal group of bodies. The resemblance between phosphoretted hydrogen and ammonia, both the result of the putrefactive fermentation of animal matter, was before adverted to; and phosphoretted hydrogen, upon the hypothesis $= \text{H N} + \text{H}^3 = \text{H}^4 \text{N}$, which is the precise composition assigned to ammonium. Further, amidogen corresponds in the number and ratio of its elements with sulphur; and sulphur, we have seen, is directly derived from nitrogen.

Thus, in every view that we can take of the chemical constitution of bodies, we are compelled to refer them to a common origin. No other hypothesis will save us from contradictory conclusions, or accord with the results which experiment has established.



III.—LAW OF CONTINUOUS COMBINATIONS



The principle of chemical combinations which I have thus far endeavoured to establish is, that from certain roots or elements, all the other bodies in the descending order, simple or compound, may be derived. We have seen, that two suppositions may, with almost equal reason, be made ; first, that all bodies may be resolved into hydrogen, carbon, and oxygen ; and secondly, that all bodies may be resolved into hydrogen and carbon. Either supposition may be adopted, and this consistently with observed results ; but the latter supposition is in accordance with the principle, that we shall not assign more causes for an effect than are necessary to explain it. If we shall suppose that all bodies are resolvable into hydrogen and carbon, as common roots, we can equally explain the resulting effects, as if we shall suppose that the roots are three, hydrogen, carbon, and oxygen.

If carbon were a simple multiple of hydrogen, then we could explain its derivation from the molecules of hydrogen, thus :—A molecule of hydrogen $h = 1$, combines with a molecule of hydrogen h , and forms the molecule $h + h = 2$. The new molecule $h + h$ combines with the molecule h , and forms the molecule $h + h + h = 3$; and this again with the molecule h ; and so on in an arithmetical series, until we reach the molecule $h + 5 h = 6 = C$.

But carbon, it appears from experiment, is not a simple

multiple of hydrogen, but is represented by 6.04, or some number approaching to 6.04. We can only, therefore, derive carbon from hydrogen, by ascending to a higher order of molecules, from which hydrogen itself is derived. Now, we may suppose that hydrogen is derived from two distinct orders of molecules, m and n . In this case, the first member of the series in the descending order is $m + n$; the second $2 m + n$, or $m + 2 n$; the third $3 m + n$, or $m + 3 n$; and so on, until we reach $x m + n$, or $m + x n = H$ or H^1 .

But if we assume that the properties of bodies are determined, not by differences in the nature of their pristine molecules, but by differences in their modes of combinations, or, in other words, in the relations in which they stand to one another, we may assume that hydrogen is derived from a single order of molecules m . In this case, $m + m$ becomes the second member of the series, $m + 2 m$ the third, $m + 3 m$ the fourth, and so on in the descending order, until we reach $H = 1$. But the series being still continued, $H = 1$ combines with m , and forms $1 + m$; $1 + m$ combines with m , and forms $1 + 2 m$; and so on, in an arithmetical progression, until we reach $1 + x m = 6.04 = C$.

But we cannot determine the value of m from any known data; for we do not know how far the division of matter may be carried. An opinion, supported by many mathematicians of the last age was, that matter was infinitely divisible. It must be conceded, that space is, mathematically, infinitely divisible, for, if space be divided by any given quantity, as 2, the half must be equally divisible by 2, and so on ad infinitum. But although space be infinitely divisible, it in no degree follows that matter is infinitely divided. We must suppose that there are limits to the division of matter; for otherwise we should involve ourselves in this conclusion, that to form a particle of matter in any finite degree exceeding an infinitely small particle, by the successive addition of its integrant parts, an infinite time would be

required. We may reasonably suppose, then, that there are limits to the division of matter, although these limits are unknown.

We cannot, however, as has been said, determine the value of the ultimate particle m . But let us suppose, for the purpose of example, that the value, or atomic weight of m , is .01, then,

The 2d member of the series,	$m + .01 = .02$
The 3d,	$= .03$
The 4th,	$= .04$
The 5th,	$= .05$
The 6th,	$= .06$
The 7th,	$= .07$
The 8th,	$= .08$
The 9th,	$= .09$
The 10th,	$= .10$
And so on to H	$= 1.00$

Now, let us suppose the same series to be continued, and we shall arrive, in the descending order, at $6.04 = C$. Thus, two definite bodies will have been formed, H and C; and from H and C, it has been seen, we can suppose every known body, and every possible combination, to be derived.

But we may suppose the series just given to be continued in the descending order, until we reach the number corresponding with oxygen. I have admitted the possibility of this result, in the supposition made, that bodies may be conceived to be resolved into hydrogen, carbon, and oxygen, or into one or more of these bodies.

We might, upon the same principle, ascend to the higher degree of generalization, and assume all bodies to be derived from the unknown form of matter m . But, if hydrogen and carbon be derived from m , in a given series, the further conclusions to be drawn, are not invalidated, because we proceed from a lower degree of generalization.

Hydrogen, then, being the first of known bodies in the series from m , and carbon the second, we may derive all

the other bodies in the descending order from these two forms of matter, just as if we began at the higher stage of generalization, and derived them all, including hydrogen and carbon themselves, from *m*. Having obtained two known bodies H and C, we can suppose these two bodies to combine, and form the binary root HC, and from this root any number of combinations to be formed. Thus, HC combines with 1 equivalent of hydrogen, and forms H^2C , as shewn in the table before given. H^2C combines with C, and forms H^2C^2 , representing, on the hypothesis, nitrogen. This, again, combines with hydrogen, forming H^3C^2 , or with carbon, forming H^2C^3 , and so on through the entire series of bodies which we term simple, and consequently through the entire series which we know to be compound. And the series of combinations, it is to be observed, is not interrupted when we arrive at the products of the organic kingdom. The essential constituents of this order of bodies are hydrogen, carbon, oxygen, and nitrogen, and two or more of these roots combining, constitute the compounds which the living world supplies. But all these substances may be derived from the common root HC, so that the law of continuous combinations applies alike to the inorganic and organic kingdoms.

The term Organic Chemistry has been recently introduced; but the term is illogical, for no branch of chemistry can be termed organic; and even when we employ the more correct expression, the chemistry of organic bodies, we may lead others into error unless we define our meaning. The principal constituents of living bodies, or bodies that have lived, are the four substances referred to, and these substances are common to both the natural kingdoms. The essential difference between the two classes of products, when we regard their chemical nature, is, that under the influence of the living principle, whatever the nature of this principle be, the roots of bodies enter into

combinations, which frequently cannot be produced by the common chemical agencies. But there is no other conceivable distinction between the two classes of products with respect to their nature and origin. They are all, we must suppose, derived from common roots, or, in other words, from the same kind of matter. Carbonic acid is no more a peculiar product of plants and animals than of minerals, and oxalic acid is merely a species of the same genus as carbonic acid, and cannot be placed in any other division of chemical compounds. Gum, starch, and sugar, are the products of plants, but are all resolvable into carbon, oxygen, and hydrogen, and, therefore, do not differ from the bodies of the inorganic kingdom, composed of the same elements, except in so far as these elements may be combined in different ratios. There can be no reasonable question, that, in either case, the constituent elements have arranged themselves, in the manner proper to each body, in conformity with the same chemical laws; and we may conclude, that the essential difference is, that the elements in the one case have obeyed the ordinary chemical affinities, and that in the other these affinities have been determined to a given end by another system of laws, to which, in our ignorance of their nature, we apply the term vital. When we, therefore, direct chemical researches to substances derived from bodies that have been once organized, we are in no respect to assume, that we have to do with a different order of matter, in so far as its chemical constitution is concerned.

Chemistry applied to the latter class of bodies, has, within our own times, made a surprising advance. But as yet this advance has been rather towards the collection of facts than towards the establishment of principles. Compound after compound is in the course of being added to the list, and no limit can be assigned to the number which may be produced. For not only may the four substances, hydrogen, carbon, oxygen, and nitrogen, into which the great mass of

substances of organic origin is resolvable, be combined in a vast number of ways ; but the compounds thus produced may combine with, or be acted upon, by such bodies as chlorine, sulphur, phosphorus, arsenic, and by the acids and other compounds formed by these bodies. We must see, therefore, that there is no assignable limit to the number of compounds that may be produced by the action of so many substances upon one another. If we proceed, as now, in adding new compounds to those already known, we may expect that chemistry will become a chaos of names and unconnected results, which will overburden the memory, unless we shall be able to reduce the scattered truths to order. Chemists, indeed, engaged in this interesting branch of inquiry, have everywhere felt the necessity of arranging the results of their experiments into something like laws. Hence, the introduction of what have been termed radicals, or roots common to a number of compounds. To this species of arrangement no logical objection exists. On the contrary, it is founded on the application of a principle, which all the analytical researches of chemistry tend to confirm, the resolution of compound bodies into others more simple. But it may be gravely questioned, whether we are now proceeding in the right direction in our method of applying the principle to the formation of roots and chemical formulæ, and are not attempting to express more by these formulæ than our knowledge will warrant. A formula should be the expression of a chemical truth, as of the ratio in which certain elements enter into a given compound ; but we should be careful, in reducing this expression of a truth to another form, to express no hypothesis which is not necessarily involved in the truth to be expressed. Yet, if I mistake not, in our construction of these hypothetical formulæ by which we endeavour to express the nature of the numerous compounds which we are now enabled to form, we are passing far beyond the limits of a just induction. Not contented with expressing the ratios in which

the several constituents exist in the compound, as determined by experiment, we divide and subdivide its several members, and assign to each its place in our formulæ, just as if we could see into the molecular constitution of a compound particle of matter : And, beyond a question, this course incautiously pursued, is tending to encumber the progress of discovery by a mass of useless hypotheses.

We do not know in what manner one molecule unites itself to another to form a compound molecule ; but we do know, that a body which is itself compound, may perform the functions of a body which we regard as simple, and, hence, we may infer, that a compound molecule may perform the functions of what we regard as a simple molecule. Hydrogen combines with oxygen, and forms water ; but water combines with other bodies, as much in the manner of a simple body as hydrogen, and the molecules of water seem to be as much simple with relation to the bodies with which water combines, as the molecules of hydrogen are simple with relation to the bodies with which hydrogen combines. Cyanogen performs the same functions in combination, as oxygen, sulphur, or chlorine ; and hence, we may believe, that the molecule of cyanogen is as much simple in its actions as a molecule of oxygen, sulphur, or chlorine. An acid combines with a base, and forms a salt. A new molecule, we may suppose to be formed, which is a molecule of this salt. But one salt may combine with another, and form a new salt. The molecules of these salts, therefore, are single with respect to one another, and enter into combination in the same manner as the molecules which we regard as simple.

Hence will appear the futility of the controversy which has recently arisen amongst chemists regarding the nature of Salts. Chlorine combines with sodium, and forms a salt. But sulphuric acid, likewise, combines with an oxide of the same metal, and forms a salt so similar to the other in its general characters, that it is impossible

not to regard them as bodies of the same class. But it is contended, that in place of supposing a molecule of sulphuric acid to combine with a molecule of soda, we must assume that the oxygen of the oxide passes over to the sulphuric acid SO^3 , and forms a new compound SO^4 , and that it is this compound which combines with the metal and forms the salt, and not the acid with the base. But this supposition in no degree explains the difficulty which it is intended to remove. We must believe that this new compound SO^4 , which has never been insulated, nor proved to exist, forms a new body, single with relation to the body with which it combines. But is not SO^3 equally in this respect single with relation to the body with which it combines? But then it is said, the base with which chlorine combines is a metal, and consequently a simple body, and, therefore, the body with which our new compound, SO^4 , combines to form a salt, must be a metal and a simple body. But it is denied that the metal is a simple body; and even if it were, the supposition would not help the argument. We admit, that a body having the properties of a simple body with respect to its mode of action, is formed by the compound S O^4 : why should we refuse to admit, that a body having the properties of a simple body, is formed by the compound Na O ? Can a single reason be given why we should assume that S O^4 is more simple than S O^3 or Na O ? The acid S O^3 is, indeed, a compound, formed of two known roots, but these roots unite to form a single body; and we must assume, that the particles of this body are as much single as the body which they have combined to form. So we must believe of the base Na O . It likewise is a single body, formed of its own particles, and these particles must be as much single as the body of which they are parts. Neither chlorine nor the metal is a simple body; and Na Cl falls within the same class of chemical combinations as $\text{Na O} + \text{S O}^3$. These latter bodies have each their own particles, as single with relation to one another,

as those of the chlorine salt ; and no necessity exists for the clumsy hypothesis which has been adopted for reducing them to the same class of chemical combinations. They are in the same class, nay, it may be said, almost in the same genus already, and the hypothesis made is superfluous, and the reasoning, therefore, on which it is founded, illogical.

Although we do not know the manner in which two orders of molecules unite to form a new and single molecule, it may be reasonably believed that it is by a simple law of combination. The molecules of H, we may suppose, combine with the molecules of C, and form the root H C. This root combines with H, and forms $H^2 C$ or oxygen, and this root again combines with an equivalent of H, and forms $H^3 C$, or water. Now these combinations appear to take place in succession, for water cannot be conceived to be formed before oxygen, nor can oxygen be conceived to be formed before the roots of which it is composed. When nitrogen is formed, it may combine with another root already produced, oxygen, forming

Nitrous oxide,	= N O
Nitrous oxide, combining with O, forms nitric oxide,	= N O ²
Nitric oxide, combining with O, forms hyponitrous acid,	= N O ³
Hyponitrous acid, combining with O, forms nitrous acid,	= N O ⁴
Nitrous acid, combining with O, forms nitric acid,	= N O ⁵

And, in like manner, when any body whatever combines with more than one equivalent of another, it is reasonable to assume that the first in the order of combination are the single equivalents, and so on through the sequence. This supposition is in strict accordance with the atomic theory of combinations, and may be said to be a consequence of it.

The following Table will shew the manner in which all bodies may be derived from the common root H C, by a series of continuous combinations or permutations ; and the table, it will be observed, may be so extended as to comprehend, not only every known root, but every possible combination.

TABLE OF CONTINUOUS COMBINATIONS.

	C	C ²	C ³	C ⁴	C ⁵	C ⁶	C ⁷	C ⁸	C ⁹	C ¹⁰	C ¹¹	C ¹²	C ¹³	C ¹⁴	C ¹⁵
H	H C	H C ²	H C ³	H C ⁴	H C ⁵	H C ⁶	H C ⁷	H C ⁸	H C ⁹	H C ¹⁰	H C ¹¹	H C ¹²	H C ¹³	H C ¹⁴	H C ¹⁵
H ²	H ² C	H ² C ²	H ² C ³	H ² C ⁴	H ² C ⁵	H ² C ⁶	H ² C ⁷	H ² C ⁸	H ² C ⁹	H ² C ¹⁰	H ² C ¹¹	H ² C ¹²	H ² C ¹³	H ² C ¹⁴	H ² C ¹⁵
H ³	H ³ C	H ³ C ²	H ³ C ³	H ³ C ⁴	H ³ C ⁵	H ³ C ⁶	H ³ C ⁷	H ³ C ⁸	H ³ C ⁹	H ³ C ¹⁰	H ³ C ¹¹	H ³ C ¹²	H ³ C ¹³	H ³ C ¹⁴	H ³ C ¹⁵
H ⁴	H ⁴ C	H ⁴ C ²	H ⁴ C ³	H ⁴ C ⁴	H ⁴ C ⁵	H ⁴ C ⁶	H ⁴ C ⁷	H ⁴ C ⁸	H ⁴ C ⁹	H ⁴ C ¹⁰	H ⁴ C ¹¹	H ⁴ C ¹²	H ⁴ C ¹³	H ⁴ C ¹⁴	H ⁴ C ¹⁵
H ⁵	H ⁵ C	H ⁵ C ²	H ⁵ C ³	H ⁵ C ⁴	H ⁵ C ⁵	H ⁵ C ⁶	H ⁵ C ⁷	H ⁵ C ⁸	H ⁵ C ⁹	H ⁵ C ¹⁰	H ⁵ C ¹¹	H ⁵ C ¹²	H ⁵ C ¹³	H ⁵ C ¹⁴	H ⁵ C ¹⁵
H ⁶	H ⁶ C	H ⁶ C ²	H ⁶ C ³	H ⁶ C ⁴	H ⁶ C ⁵	H ⁶ C ⁶	H ⁶ C ⁷	H ⁶ C ⁸	H ⁶ C ⁹	H ⁶ C ¹⁰	H ⁶ C ¹¹	H ⁶ C ¹²	H ⁶ C ¹³	H ⁶ C ¹⁴	H ⁶ C ¹⁵
H ⁷	H ⁷ C	H ⁷ C ²	H ⁷ C ³	H ⁷ C ⁴	H ⁷ C ⁵	H ⁷ C ⁶	H ⁷ C ⁷	H ⁷ C ⁸	H ⁷ C ⁹	H ⁷ C ¹⁰	H ⁷ C ¹¹	H ⁷ C ¹²	H ⁷ C ¹³	H ⁷ C ¹⁴	H ⁷ C ¹⁵
H ⁸	H ⁸ C	H ⁸ C ²	H ⁸ C ³	H ⁸ C ⁴	H ⁸ C ⁵	H ⁸ C ⁶	H ⁸ C ⁷	H ⁸ C ⁸	H ⁸ C ⁹	H ⁸ C ¹⁰	H ⁸ C ¹¹	H ⁸ C ¹²	H ⁸ C ¹³	H ⁸ C ¹⁴	H ⁸ C ¹⁵
H ⁹	H ⁹ C	H ⁹ C ²	H ⁹ C ³	H ⁹ C ⁴	H ⁹ C ⁵	H ⁹ C ⁶	H ⁹ C ⁷	H ⁹ C ⁸	H ⁹ C ⁹	H ⁹ C ¹⁰	H ⁹ C ¹¹	H ⁹ C ¹²	H ⁹ C ¹³	H ⁹ C ¹⁴	H ⁹ C ¹⁵
H ¹⁰	H ¹⁰ C	H ¹⁰ C ²	H ¹⁰ C ³	H ¹⁰ C ⁴	H ¹⁰ C ⁵	H ¹⁰ C ⁶	H ¹⁰ C ⁷	H ¹⁰ C ⁸	H ¹⁰ C ⁹	H ¹⁰ C ¹⁰	H ¹⁰ C ¹¹	H ¹⁰ C ¹²	H ¹⁰ C ¹³	H ¹⁰ C ¹⁴	H ¹⁰ C ¹⁵
H ¹¹	H ¹¹ C	H ¹¹ C ²	H ¹¹ C ³	H ¹¹ C ⁴	H ¹¹ C ⁵	H ¹¹ C ⁶	H ¹¹ C ⁷	H ¹¹ C ⁸	H ¹¹ C ⁹	H ¹¹ C ¹⁰	H ¹¹ C ¹¹	H ¹¹ C ¹²	H ¹¹ C ¹³	H ¹¹ C ¹⁴	H ¹¹ C ¹⁵
H ¹²	H ¹² C	H ¹² C ²	H ¹² C ³	H ¹² C ⁴	H ¹² C ⁵	H ¹² C ⁶	H ¹² C ⁷	H ¹² C ⁸	H ¹² C ⁹	H ¹² C ¹⁰	H ¹² C ¹¹	H ¹² C ¹²	H ¹² C ¹³	H ¹² C ¹⁴	H ¹² C ¹⁵
H ¹³	H ¹³ C	H ¹³ C ²	H ¹³ C ³	H ¹³ C ⁴	H ¹³ C ⁵	H ¹³ C ⁶	H ¹³ C ⁷	H ¹³ C ⁸	H ¹³ C ⁹	H ¹³ C ¹⁰	H ¹³ C ¹¹	H ¹³ C ¹²	H ¹³ C ¹³	H ¹³ C ¹⁴	H ¹³ C ¹⁵
H ¹⁴	H ¹⁴ C	H ¹⁴ C ²	H ¹⁴ C ³	H ¹⁴ C ⁴	H ¹⁴ C ⁵	H ¹⁴ C ⁶	H ¹⁴ C ⁷	H ¹⁴ C ⁸	H ¹⁴ C ⁹	H ¹⁴ C ¹⁰	H ¹⁴ C ¹¹	H ¹⁴ C ¹²	H ¹⁴ C ¹³	H ¹⁴ C ¹⁴	H ¹⁴ C ¹⁵
H ¹⁵	H ¹⁵ C	H ¹⁵ C ²	H ¹⁵ C ³	H ¹⁵ C ⁴	H ¹⁵ C ⁵	H ¹⁵ C ⁶	H ¹⁵ C ⁷	H ¹⁵ C ⁸	H ¹⁵ C ⁹	H ¹⁵ C ¹⁰	H ¹⁵ C ¹¹	H ¹⁵ C ¹²	H ¹⁵ C ¹³	H ¹⁵ C ¹⁴	H ¹⁵ C ¹⁵

Of the roots which chemists have considered to be well established, and to perform the part of single bodies, in so far as their chemical actions are concerned, are

Formyl,	.	= H C ²
Methyl,	.	= H ³ C ²
Acetyl,	.	= H ⁴ C ³
Ethyl,	.	= H ⁵ C ⁴
Amyl,	.	= H ¹¹ C ¹⁰
&c.		

Now, all these roots will be found in their several places in the table, each derivable by a series of continuous combinations from the common root H C. Further, the formulæ of these bodies may be reduced to a simpler expression, thus :—

Formyl,	.	H C ² = H C + C
Methyl,	.	H ³ C ² = 2 H C + H
Acetyl,	.	H ⁴ C ³ = 3 H C + H
Ethyl,	.	H ⁵ C ⁴ = 4 H C + H
Amyl,	.	H ¹¹ C ¹⁰ = 10 H C + H
&c.		

And whichever of those formulæ we adopt to express the root, the same number of continuous combinations will be required to form it. Thus, the expression for ethyl being H⁵ C⁴, it will be seen from the table, that 8 successive combinations must have taken place, namely, H + C, H + C + H, and so on to H⁵ C⁴. If, again, we adopt the second expression, 4 H C + H, we have, in like manner, 8 combinations, namely, H with C four times, and these roots, again, with one another, and, lastly, with hydrogen, to form 4 H C + H. Again, ethyl, H⁵ C⁴, combines with 1 equivalent of oxygen and forms ether, H⁵ C⁴ + O. But O = H² C, and ether, therefore, = H⁵ C⁴ + H² C = H⁷ C⁵. Looking to the table, we shall see that this compound, H⁷ C⁵, is produced by 11 successive combinations; and we shall see, that if we re-

present ether by E + O, the same number of combinations or permutations is required to produce, 1st, ethyl, 2d, oxygen, and 3d, the combination of oxygen and ethyl : and the same thing is true of any other compound which we can form, or suppose to be formed.

I have thus, I conceive, shewn, that the bodies termed simple, are not simple but compound, and cannot be separated from other chemical products, by any such distinction as simple and compound ; and if it shall be admitted that we have justly arrived at this conclusion, and that all bodies in the descending order may be resolved into two of their own order, H and C, by a series of continuous permutations, then we may reduce the formulæ of all bodies formed of these elements to a simple expression. For x , representing the unknown co-efficient of the root H C, and y and z of the elements H and C respectively, the following formula will represent the roots themselves and every possible combination of them :—

$$x \text{ H C} + y \text{ H} + z \text{ C}.$$

Thus, if x be 1, and y and z , 0, the formula will represent the root H C ; and thus the following, and any other combinations, may be represented.

Oxygen,	.	$\text{H}^2 \text{ C}$	$=$	$\text{H C} + \text{H}$
Nitrogen,	.	$\text{H}^2 \text{ C}^2$	$=$	2 H C
Phosphorus,	.	$\text{H}^3 \text{ C}^2$	$=$	$2 \text{ H C} + \text{H}$
Sulphur,	.	$\text{H}^4 \text{ C}^2$	$=$	$2 \text{ H C} + \text{H}^2$
Fluorine,	.	$\text{H}^6 \text{ C}^2$	$=$	$2 \text{ H C} + \text{H}^4$
Chlorine,	.	$\text{H}^{11} \text{ C}^4$	$=$	$4 \text{ H C} + \text{H}^7$
Arsenic,	.	$\text{H}^{13} \text{ C}^4$	$=$	$4 \text{ H C} + \text{H}^9$
Antimony,	.	$\text{H}^{16} \text{ C}^8$	$=$	$8 \text{ H C} + \text{H}^8$
Bismuth,	.	$\text{H}^{23} \text{ C}^8$	$=$	$8 \text{ H C} + \text{H}^{15}$
Copper,	.	$\text{H}^{15} \text{ C}^8$	$=$	$8 \text{ H C} + \text{H}^7$
Tin,	.	$\text{H}^{10} \text{ C}^8$	$=$	$8 \text{ H C} + \text{H}^2$
Lead,	.	$\text{H}^{19} \text{ C}^{14}$	$=$	$14 \text{ H C} + \text{H}^5$
Silver,	.	$\text{H}^{24} \text{ C}^{14}$	$=$	$14 \text{ H C} + \text{H}^{10}$

and so on.

I have now brought my argument to a conclusion ; and it will be seen, that, on the suppositions made, the result is not affected, whether we commence our generalization with the roots H, C, and O, formed of three known bodies, or with the roots H, C, formed of two known bodies, or whether we derive these bodies from forms of matter which we represent by m and n , or from a form of matter which we represent by m alone, or any other expression for an unknown quantity. I am aware that many important consequences must follow the more extended generalization ; but I have not felt it necessary, for the purposes of my present argument, to pursue this train of inquiry to its results. I am contented for the present to offer such views of chemical combinations as may, in the existing state of our knowledge, be reasonably assented to. We are not the less likely to succeed in our search of chemical truths, that we advance with caution from particulars to generals, and feel the ground secure beneath us as we proceed. Chemistry may be said to be at present in that state of transition, in which the knowledge of facts has preceded the knowledge of principles ; but we cannot doubt that in this, as in other branches of inductive science, the discoverers of facts will be overtaken by theory, and that thus their matchless labours will be reduced to method and form.

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